Water Development, Supply and Management, Volume 8
WATER AND SOCIETY, Conflicts in Development, Part 2

Water Conflicts and Research Priorities

Edited by
Carl Widstrand

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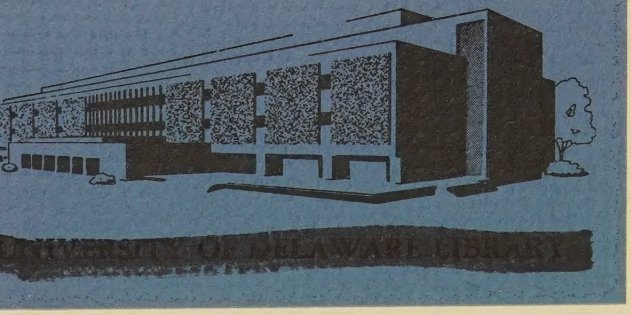
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WATER DEVELOPMENT, SUPPLY AND MANAGEMENT

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Volume 8

WATER AND SOCIETY

CONFLICTS IN DEVELOPMENT

Part 2

Water Conflicts and Research Priorities

WATER DEVELOPMENT, SUPPLY AND MANAGEMENT

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WATER AND SOCIETY

CONFLICTS IN DEVELOPMENT

Part 2

Water Conflicts and Research Priorities

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PREFACE

Over the last decade, vast amounts of resources have gone into the provision of water installations for rural and urban populations. Substantial amounts have gone into rehabilitation and construction of irrigation systems for agriculture. At the same time, global statistics present a discouraging picture of water supply and sanitation, particularly in rural areas. The paradox of a modern water conveyance system presents itself: in areas with excellent climate for year-round farming, solar energy and good soil, water resources give very low crop yields.

There is obviously a need for some other kind of knowledge. The research project, *Water Related Problems in Developing Countries*, was started precisely to look into this question. We wanted to produce a summary overview of the present knowledge of social, cultural and ecological aspects of water exploitation, identify some gaps in research and suggest some areas for further research. This was a tall order and quite early we restricted our geographical coverage to East Africa and the Indian subcontinent and our thematic coverage to rural drinking water supplies and irrigated agriculture. We have also focused our attention on social aspects and a major part of the survey is conceived as a study on conflicts in the use and development of water resources. This means that we have left all problems concerned with choice of technology to other authors.

The research project was financed by the Swedish Agency for Research Co-operation with Developing Countries (SAREC) and the Swedish Committee for Future-Oriented Research (DALFO). The study was originally meant for a Swedish public, which may explain why we sometimes deal with aspects which may be well known. We are grateful to Pergamon Press for their contribution to the production of this volume and the earlier companion volume.

The text of the volume should be regarded as a joint production effort of the team of authors. As a basis for discussion, texts have been produced for Chapter 2 by M. Falkenmark and Chapters 3, 5 and 6 by Carl Widstrand, with contributions by Lennart de Maré and for Chapter 4 by Gunnar Lindh.

It is also our pleasant duty to convey our thanks to Dr. Robert Chambers and Anthony Bottrall for good advice on irrigation management problems and to Ms Sonja Johansson and Ms Carmen Uhr of the Scandinavian Institute of African Studies at Uppsala and Ms Ingegerd Eriksson, Secretariat, Committee for Hydrology, Natural Science Research Council, Stockholm for their patient typing of large parts of the manuscript.

Uppsala, Stockholm and Lund,
August 1979

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CHAPTER 1

Development and Availability of Water

INTRODUCTION

Conventional wisdom holds that improved water supplies will abolish disease and increase agricultural production.

The UN Conference in Mar del Plata in 1977 set the goal of a safe rural water supply to be universally reached in 1990. That is ten years from now. Improved water conservation was another of the goals discussed at Mar del Plata, and such improvements would create self-sufficiency in food production.

The diseases of poverty to which belong many of the so-called tropical diseases probably decrease with an increased economic standard, as is witnessed by the social history of tuberculosis in Europe.

Every country in the world could be self-sufficient in food production if major obstacles such as distribution problems based on basic inequalities could be done away with.

However, it is probably true that water is a major input—but only one input among many—in the struggle against starvation and disease.

The Mar del Plata conference goals are again formidable. In one single decade, a safe water supply should be expanded to a population three times larger than that which at present has such supplies. The total area under irrigation has to be increased by 25 per cent in ten years. Half the area which at present is non-productive due to waterlogging and salinization must be rehabilitated.

If we accept these goals, and if they are not only to become pious wishes it is quite clear—whether we want it or not—that during the next decade technical assistance and transfer of knowledge from industrialized countries to developing countries will continue to play a central role. In the past, however, such transfer processes have not been very successful in the field of water resources development. The reports and discussions in the preceding volume (Widstrand 1978) pin-pointed a number of facts of central relevance for the failures encountered. For instance, irrigation and water supply projects have met numerous unexpected problems arising when projects have been introduced that are socio-culturally alien to the new environment. Many such problems are software problems. A major problem has been that planners of rural water projects are quite often trained in

industrialized countries, and therefore used to sophisticated systems with a technology that cannot be sustained by local people when the expatriate engineers have left. In the absence of ex-post evaluation as a routine process in planning, numerous planning mistakes have been endlessly repeated. In consequence, it seems that there is, here, need for a new strategy with a more general acceptance of the simple fact that being wrong is a creative part of the learning process.

The aim of this book is to look into a number of central problems in order to see where to find the most relevant gaps of knowledge and how research might be directed to support the intended development. An important way of doing this is to analyse some mistakes of the past and to delineate some limits and constraints of the process of transfer of knowledge from one physical and socio-cultural environment to another.

OLD PROBLEMS REVISITED

The problems reviewed in this book are not new. Some have existed in the same areas for thousands of years. Conflicts generated by fossilized bureaucracies have a long tradition.

Irrigation systems in Mesopotamia, ancient Egypt and indeed in the Roman world, China and in mediaeval Europe, have had the same general problems of distribution of water, of communal labour and collective responsibility for water courses, of unwilling participants.

Conflicts over water use and extraction, and over water rights, occupied Roman lawyers and mediaeval judges of Valencia's *Tribunal de las Aguas*. Government and central control of waterways or irrigation water has been in conflict for centuries with the farmer and his ideas of agriculture. (Forbes 1955, Stevens 1971, Glick 1970.)

Individual quarrelling about water rights was a permanent factor in Chinese life (Needham 1971) and quarrels over the measuring of irrigation time were not unheard of in mediaeval Spain (Glick 1969).

Problems of water conservation and of heavy erosion have been a constant feature for centuries in the Mediterranean region (Stevens 1971), and salinization, waterlogging and problems of deficient drainage are very old.

It is probably true that the origins of artificial supplies of water for domestic purposes are closely bound up with irrigation (Clark 1944). Methods of lifting water or conducting it from distant sources created immediate problems of operation and maintenance of installations (Forbes 1955).

The obvious conclusion that many features of water handling during historical times are also encountered as problems in the same areas today, leads to two further sets of problems: (1) the question of re-use of old irrigation systems and (2) problems concerning the political implications of the administration of large scale irrigation works.

In both cases, it is important to recall that there are two basic types of irrigation canals: inundatory and perennial. Inundatory canals are filled with water only during floods; perennial canals draw water for the fields at all times of the year. As Butzer, and indeed Willcocks early in this century, points out, this constitutes the difference between the Babylonian-Mesopotamian irrigation systems, which are fed at all times during the year, and the Egyptian, which depended on the annual flooding of the Nile. Perennial irrigation in Egypt was not introduced until this century (Butzer 1976, Willcocks 1911, 1913, Needham 1971).

Concerning the re-use of ancient installations we can be rather brief. Ancient installations have been "restored" with some success in the Negev desert (Evenari *et al.* 1975) and similar work has been suggested for the former Roman North Africa (Stevens 1971). Some parts of the Grand Anicut system from the second century AD on the Cauvery River near Tanjore in South East India are still in use (af Edholm 1977), but in most instances the old installations have been abandoned for good reasons such as salinization, and would take an inordinate amount of time and money to rehabilitate.

Irrigation systems in the Orient and on the Indian subcontinent are run basically according to the same methods as six thousand years ago, albeit with a more modern technology.

The importance of water to the societies which developed along the Euphrates, the Tigris and the Nile led Wittfogel to propound a theory of water control as a foundation for early civilizations (Wittfogel 1957). His main argument (partly from Steward 1949, 1955) was that waterworks for agricultural purposes were so extensive and so important that a well-organized cooperation was needed for their construction, administration and maintenance. This, in turn, led to a need for centralized decisions from which a certain type of political centralization and hierarchy developed, what Wittfogel called "oriental despotism". The debate about the connection between irrigation systems, political organization and the so-called Asiatic mode of production still continues. (Hunt and Hunt 1976, Anderson 1974, Hindes and Hirst 1975, Leach 1961, Sanders and Price 1968, Mitchell 1973, Mayes 1977, Crevenna 1955, Bennet 1974.)

Many authors have refuted the notion that irrigation is a "reason for the development of centralized bureaucracies and authoritarian political patterns". Leach (1959) shows that such a development is unnecessary and points out that the time factor is important and that irrigation systems in Sri Lanka, which look very impressive, have taken many hundred years to construct.

Others have proposed that power is the basis for control of water rather than control of water being the basis for power. Impressive systems do not imply impressive government (Glick 1970, Djurfeldt and Lindberg 1975). Several authors have raised the question whether the managerial functions implicit in irrigation may not be performed through local community leadership rather than a central authority (Beals 1955, Butzer 1976). Here mention may be made of the rather impressive irrigation systems existing in East Africa among peoples like the Chagga and the Sonjo in northern Tanzania, the Marakwet in Kenya (Gray 1963, Masao 1974). Large scale irrigation works also exist at the Angaruka site in Tanzania, recently reassessed by Sutton (1978). He points out that all the groups practising irrigation in East Africa belong to chiefless societies and regulate their waterworks through councils or "water boards" institutionally separate from the main political structures.

One may also look at the different emphasis on large scale water use in various parts of the world. In a historical account embracing irrigation development from Babylonian times to eighteenth century Europe, Needham (1971) points out that although irrigation was important in China, the main emphasis was on river control and inland water transport.

The supposition that underlies the Wittfogel theory—"this vulgar charivari, devoid of any historical sense" (Anderson 1974)—that public-works projects at any time and in any society are always carried out in the same way does not hold true (Glick 1970). The gap between a general theory of "hydraulic society" and recent studies of irrigation and other public waterworks is still wide.

RELATIONSHIPS BETWEEN DEVELOPMENT AND AVAILABILITY OF WATER

The importance of the role of water in societal development is not very well known. Evidently, water constitutes only one input among numerous others that are equally necessary for the process of development. On the other hand, water plays a key role in health development. According to the experience in industrialized countries, it also constitutes an important lubricant of modern society.

(1) Studies on the Relation between Development and Availability of Water

Present knowledge does not allow us to make any definite statement about the relationship between development—defined in some precise manner—and availability of water in quantity and quality. We know how much water is needed for human survival in a certain climatic zone. As an example, in arid zones 100 litres per person and day are allowed for in new water schemes. This is far less than the 400 litres used today in the large cities of Europe (Burton 1977).

Starting thus from this minimum survival value, one may attempt to find out graphically how increasing availability of water may affect development. Such a graph can be expected to have the shape of a logistic-like curve, which means that a saturation value will be reached indicating that additional water cannot be used for any meaningful development (Fig. 1:1). For a certain society the two extreme values may perhaps be calculated.

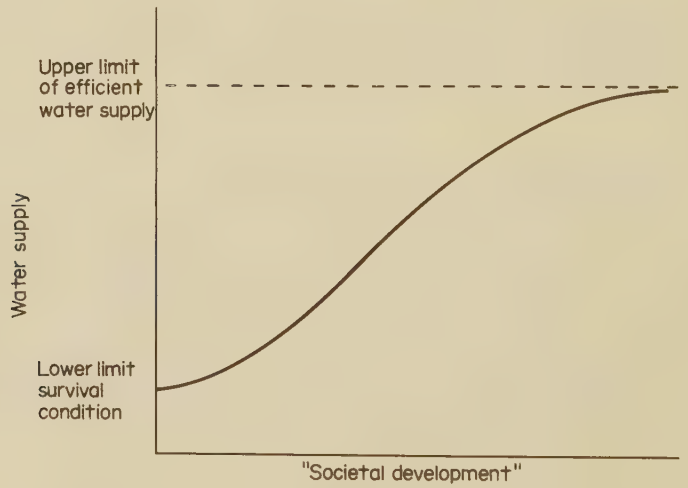


Figure 1:1 Quantity of water supplied and stimulation of societal development

Unfortunately we do not know enough about the details of this relationship. The hypothesis has been put forward that in less developing countries the development more or less follows the dotted curve in Fig. 1:2. This is due to the fact that there may be an eagerness to attain advanced standards as quickly as possible. In such cases, too much capital and labour would be put in during the early phase of development.

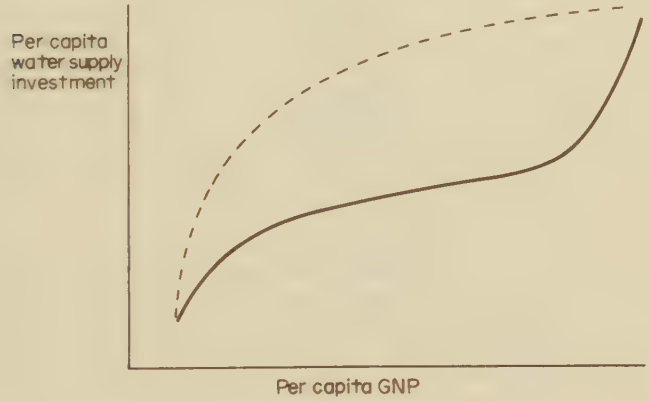


Figure 1:2 Hypothetical relation between per capita water supply investment and per capita GNP

Fig. 1:2.

Burton and Lee (1974) tried to find a relationship between GNP and water availability but were unable to find any unique relationship. "Development" is probably not uniquely identified through GNP. On the other hand, Vlachos and Hendricks (1977) point out that availability of water is a necessary factor for economic development but not a sufficient one. Only in some special cases will water be a decisive factor, as for instance in the development of an irrigation project, where, however, the presence of other factors are needed to reach an optimal result.

We may analyse this complex role of water a little further by noting that there have been attempts to distinguish between primary effects and effects of a higher order (Vlachos and Hendricks 1977). Primary effects can be recognized as the direct result of some water activity, whereas secondary impacts or long-range consequences, without going into details, are said to be of interactive, diachronic or cumulative character. Those three expressions reflect an interactive totality over time. In other words, it is not quite certain that impacts by themselves will have significance, but rather the impacts considered together over a long time (Fig. 1:3).

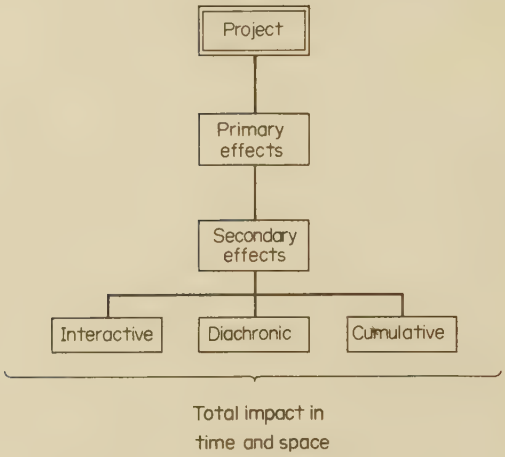


Fig. 1:3.

As an example of this, let us regard river water diverted to a hydroelectric power station. Water is necessary for the activity of the power station, but the consequences of water availability are much more far-reaching if we observe the nearby or far distant communities that in various ways make use of the electricity generated by the river water. Because of the multifarious use of energy, any attempt to see how water in a certain quantity may contribute to development would be hidden already because of the difficulty in expressing how development corresponds to the different uses of energy.

The fact that development has to be considered as composed of tangible as well as intangible factors may be of importance in explaining why availability of water may not be uniquely correlated to GNP. Galtung and Wirak (1977), among other authors, underline that even societies undergoing rapid economic growth as measured by GNP *per capita* often seem incapable of satisfying even the basic needs of their population. On the other hand, some economic systems more directly aiming at satisfaction of basic needs may at the same time satisfy also a number of basic non-material needs. Mabogunje (1972), broadens the aspect of distinguishing between economic growth and economic development by the fundamental thesis that one can have the one without the other.

(2) Competition between Industrial and Agricultural Development

It has been shown that the idea of national development in less developed countries is more or less characterized as competition between industrial and agricultural development, (Hodder 1976; and UN Centre for Development Planning, 1975). Although the character of such competitive development turns out to be quite different in different countries, there generally seems to be three aspects as to the appropriate and important choice between industry or agriculture as the primary sector.

Firstly, the opinion exists that increased agricultural production is the only sure foundation for successful industrialization at a subsequent stage in the development of an economy, (Reynolds 1975). The second point of view is that rapid expansion in industrialization is regarded as the only way to choose whether the developing country should be able to reach the same standard as a developed country. Thirdly, there exists the more modest view that the truth is somewhere in between these two opinions, i.e., there must be a joint development of industry and agriculture.

As a matter of fact, both sectors need water, but for most developing countries it has been easier to delineate programmes for manufacturing production than for agricultural output. The main reason for this seems to be that industrial activities take place in urban areas and are therefore concentrated. Agricultural production, which takes place in villages and hamlets, is scattered all over the country. Of course, concentration makes it easier for planners and decision-makers to handle the situation. There may also exist something of a psychological conflict between these two areas because industry commonly has been characterized as an "engine of modernization". In developing countries modernization attracts particular interest, and governments have hitherto very often acted in favour of industrialization.

The preference given to either industrialization or to agriculture in fact reveals an interest in achieving a high rate of total growth for total production. In recent days, it has been pointed out, however, that an economic growth is a necessary, but by no means a sufficient, condition of progress. Steps have also to be taken to guarantee that the fruits of such an expansion are distributed among different population sectors, as well as among different regions of the country concerned (UN Centre for Development Planning 1975).

(a) Increased emphasis on agriculture

It is remarkable to see that agriculture appears to be receiving greater attention now in the plans of developing countries (Table 1:1). A mean value for the developing countries during the latter part of the 1970s of about 5.5 per cent should be compared with the average annual increase of not much more than 2.5 per cent that was achieved during the first half of the 1970s in agriculture. It is a striking fact that of thirty-three countries nineteen plan to increase agricultural production at an annual rate of 5 per cent or more. Of these countries, Venezuela attempts to reach a rate of nearly 10 per cent, and Brazil, Bolivia, Democratic Yemen, Guatemala, Iran and Jordan a rate of 7 per cent or more. For some other countries (Algeria, Bangladesh, Burma, Costa Rica, El Salvador, Indonesia, Mali and Sierra Leone) the planned actual increase as concerns agriculture seems to be in the range of 4 to about 5 per cent.

In many other respects Table 1:1 is interesting. It shows that countries with a comparatively high planned growth of gross domestic product (8 per cent or more) are mainly countries that have also planned a comparatively high annual rate of expansion in manufacturing as well as in agricultural output. Moreover, countries as, for instance, Guatemala and Indonesia, which have planned a relatively moderate yearly expansion of GNP, have envisaged a relatively high rate in just one of the two major sectors under consideration. And, finally, there is a group of countries that have foreseen a comparatively low rate of growth of gross domestic product, and their interest is to expand at least one of these two sectors of activity by a below-the-average rate.

As a complement, it must be pointed out that, besides activities in agriculture and manufacturing, other sectors also may be especially important.

TABLE 1:1

CONFIGURATION OF COUNTRIES ACCORDING TO PLANNED ANNUAL RATES OF INCREASE IN AGRICULTURAL AND MANUFACTURING PRODUCTION FROM BASE YEAR TO FINAL YEAR OF PLAN[a]

Country group	Country and planned annual rate of increase in agricultural and manufacturing production, respectively (percentage)				Number of countries
	5 per cent or more in agriculture		4 per cent or more but less than 5 per cent in agriculture		
	10 per cent or more in manufacturing	8 per cent or more but less than 10 per cent in manufacturing	10 per cent or more in manufacturing	8 per cent or more but less than 10 per cent in manufacturing	
Countries indicating a planned annual rate of growth of gross domestic product of 8 per cent or more	Iran 7.0, 37.5* Jordan 7.0, 26.2* Brazil 7.0, 12.2 Ecuador 5.3, 10.1* Democratic Yemen 7.5, 17.5* Nigeria 5.0, 18.0 Malawi 5.5, 11.8* Malaysia 6.0, 12.0 Venezuela 9.6, 13.7 Kenya 7.2, 10.2	Botswana 5.5, 8.1	Algeria 4.2, 18.8		12
Countries indicating a planned annual rate of growth of gross domestic product of 6 per cent or more but less than 8 per cent	Argentina 6.5, 10.1	Bolivia 7.4, 9.8 Guatemala 7.0, 9.0 Philippines 5.0, 9.7 Nicaragua 6.2, 9.6 Chile 6.2, 9.0	Costa Rica 4.7, 10.6 Indonesia 4.6, 13.0 Mali 4.5, 11.7* El Salvador 4.8, 10.2 Sierra Leone 4.6, 10.6	Morocco 3.6, 9.8 Panama 5.7, 7.0 Mauritius 2.0, 20.6*	14
Countries indicating a planned annual rate of growth of gross domestic product of less than 6 per cent				India 3.9, 8.0 Bangladesh 4.6, 7.1* Afghanistan 3.9, 10.2* Barbados 5.5, 4.2* Burma 4.0, 7.5 Nepal 3.5, ... Madagascar 3.0, 4.3	7
Number of countries	11	6	6	0	10	33

Source: UN Centre for Development Planning (1975) Table 3.

[a]An asterisk (*) indicates that data refer to both mining and manufacturing.

Countries are listed in each category in descending order of their planned annual rate of growth of gross domestic product, as shown in Table 1 of source.

For other details and differences in concepts, see footnotes to Table 3 of source.

(b) Agricultural sector grows more slowly

There is a pronounced aim of most developing countries to strive at a high rate of growth for total production. In spite of an accelerating agricultural sector it is a remarkable fact that this sector may be expected to grow more slowly than the total production. The statistics in Table 1:1 show only two exceptions—Barbados and Venezuela.

Several developing countries have indicated that the agricultural sector will be the dominating sector also in the foreseeable future. Agriculture is expected to contribute more than half of the production of goods and services in such countries as Afghanistan, Bangladesh and Nepal. Similar percentages may be quoted from other countries situated in Africa or Asia. As to the countries in Latin America, their policies seem to be much more diversified.

The declining share of agriculture in the total output of goods and services and the increasing share of manufacturing turns out to be typical in most developing countries. As an example of this we can, for instance, take Iran and Jordan. If the initial plans for a five-year period really will be achieved, the share of mining and manufacturing in total output will amount to 65 per cent in Iran and 28 per cent in Jordan. Increased emphasis on mining and manufacturing is a clear tendency in many countries in the developing world, even if percentages expected are not of the same order as for the two countries mentioned. As far as industrialization is concerned, the lead of Latin American countries seems to be retained over the developing countries of Africa and Asia, as evidenced by figures not given here on targets indicated in current plans.

(c) Increased stress on environmental protection

A very interesting complement to this discussion of the importance of industrialization is the question of improvement of the natural environment that seems to have gained some prominence in some of the developing countries. In several countries (for instance Brazil, Iran and Malaysia), important objectives have been set up in order to preserve, improve and rehabilitate the environment. Measures are proposed in order not to destroy or disturb the ecological balance. Kenya may also be mentioned as a country where emphasis has been put on conservation policies, especially focusing on the protection of wildlife. This may be seen as a natural undertaking as wildlife is one of the resources on which Kenya's tourism is based. Mali and Senegal may also be mentioned because these countries have proposed measures to be taken as a consequence of a long period of dry years which has very severely damaged the economy.

SOME KEY COMPONENTS FOR AVOIDING PAST MISTAKES

The authors intend to focus in the following chapters on a number of central issues which have to be seen as key components when striving at a more realistic approach towards making better use of water in the development of better living conditions.

(1) Water has to be seen as a transient resource continuously circulating in the gigantic desalination system referred to as the hydrological cycle. The availability of this resource varies strongly both in time, in space, and in quality. The physical laws of this system imply a geographical distribution which makes all people living in the same river basin mutually interdependent.

(2) Due to the character of the hydrological processes, water is closely connected to land use. Changes in the soil surface and vegetation thus involve changes in the water availability pattern, (as regards both seasonal variations and quality characteristics). The close interaction between man, water, soil and vegetation implies that environmental effects of water projects are more or less inevitable. Therefore, the real question is not whether water development projects will affect the environment, but rather how much change is acceptable.

(3) In order to satisfy man's water-related needs water has to be mastered and redistributed in both time and space. Basically the hydrological system is manageable and the intended adaptation of the natural system to society could be reached. Unless there is a close adaptation also to social reality, water, however, remains unmanageable. Water development therefore necessitates a successful application of natural sciences as well as social sciences.

(4) It would be wise to accept that future water planning has to depart from past mistakes. In consequence, equal attention has to be paid to choice of adequate technology, to construction, to operation and maintenance, to man-management, and to avoiding the risk of long-term environmental deterioration.

(5) In the process of making better use of water, water conflicts have to be analysed and mechanisms for their solution looked for. This includes conflicts between short-term benefits and long-term environmental deterioration, ministerial level conflicts, conflicts between government and farmers and between farmers themselves as well as conflicts between donor agencies on the one hand and governments and local groups on the other.

(6) As a tool for achieving better quality of life, a gigantic role is to be played by education and communication. This includes health education of the general public, the education of locals in water basics by extension services to peasants and farmers, education of technical personnel in the elements of water development, and education of local as well as expatriate experts thereby paying adequate attention to risks from different kinds of biases, climatic as well as cultural.

CHAPTER 2

Water and Land — Interdependent but Manipulated Resources

INTRODUCTION

(1) Close Interaction between Water and Land

Water and land constitute the basic resources for man's activities.

Man and water are closely related to each other in a dualistic manner. On the one hand, man is highly dependent on water, not only for his survival but for numerous functions of society. Making use of water and seeking protection from water are in fact prerequisites for all social development. On the other hand, this dependence forces man to intervene in numerous ways with the natural water circulation system, thereby causing modifications of water circulation, runoff formation, as well as water quality.

An equally important base for societal development is constituted by land. Its resources are used primarily for agricultural production of food and fibre, but also for industrial production based on local mineral resources.

Water and land are directly interconnected as water passes through land and the different soil layers on its way to the river draining the area. In fact, soil cover and vegetation form a key zone in the runoff formation process, determining the relative proportions between rapid flood waters and delayed groundwater-based runoff forming the dependable river flow. Any manipulations of the land surface involving major modifications of the land-soil-vegetation system are reflected in changes both of the yield and the seasonality of the runoff.

The chemical interaction between the passing water and the surrounding soil influences the chemical characteristics of the water, which is therefore susceptible to changes due to man-made manipulations with the system. Understatement of the interconnections of the system leads to vast and serious problems, either in the form of uncontrolled erosion and sedimentation, or of waterlogging and salinization of arable land. This chapter approaches water as a resource. It starts by discussing some major characteristics of water availability, seeing water as a transient resource due to its role in the hydrological cycle. Aspects especially stressed are water assessment, water seasonality, interannual variations, and regional differences in water availability causing a climatic bias to which better attention has to be paid. The chapter then focuses on some interrelations between water and land use: first the importance of

land use for the water demand, then some implications of the physical interactions between water, soil and vegetation. The chapter closes with a discussion of the extremely important but not always observed interdependence between soil conservation and water conservation.

(2) The Transient Nature of Water

The basic characteristic of water seen as a resource is its mobility. Individual water sources are interactive parts of the same system. Therefore, they cannot be handled as isolated from one another. The utilization of one inevitably affects the behaviour of the others.

Functional uses of water can be flow-related or site-related. For site-related uses as recreation, fishing, navigation, etc., relevant resource characteristics include site, beauty, water quality, water depth, although some of them are dependent also on a certain water flow. The most central water uses are flow-related. Most standard texts on water start with information on the volumes of water present in different storages. More important characteristics with regard to human use are definitely the mobility of water, the size of the water flow-through, and the renewal of different water environments.

In other words, water renewal and the recharge of water storages constitute key concepts in all long-term planning of water development and management.

(3) Interaction between Water Processes

On the global macroscale the global system acts as one single integrated system, composed of a number of interconnected subsystems. Although details are poorly known, such a unit could be seen as a main circulation cell formed around an evaporation centre in the subtropic ocean by the wind system (Keller 1961). The system of the dominating winds and the high mountain ridges combine in separating different cells from each other. In each of these cells, the evaporated water is thus diverged from subtropical latitudes to the land areas supplied with water from that region (Fig. 2:1a).

The interconnection between hydrological processes (such as between wind patterns and rain, land evaporation and rain, and between river runoff and sea evaporation) was understood in Eastern Asia already in the third century before Christ (Needham 1959).

> "The waters flow eastwards from their sources, resting neither by day nor by night. Down they come inexhaustibly, yet the deeps are never full. The small (streams) become large and the heavy (waters in the sea) become light (and mount to the clouds). This is (part of) the Rotation of the Tao."

When seen on the regional scale, the basic circulation unit is the river basin, and the hydrological processes transforming precipitation into groundwater and runoff are generally considered with the river basin as the module, although under purely arid conditions, this view may be questioned.

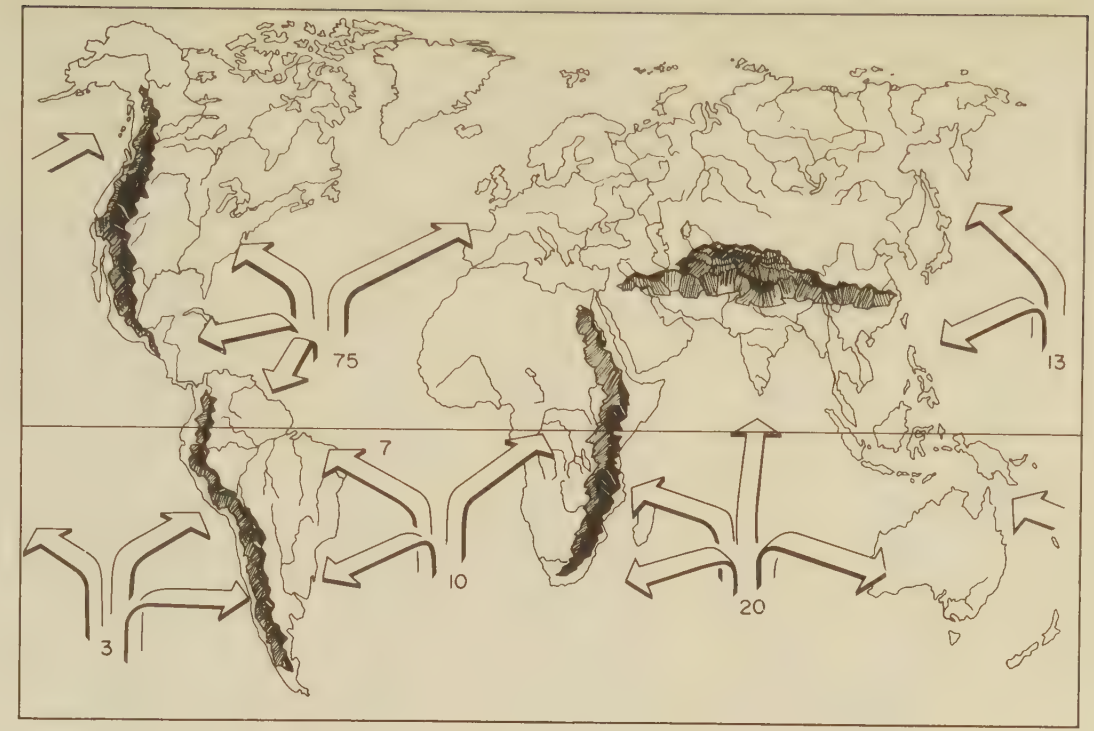


Fig. 2.1a. The global water distribution system can, when simplified, be seen as consisting of five main circulation cells, formed by the combined effects of oceanic evaporation patterns, general wind systems and location of high mountain ranges. The cells are centred in the subtropical lattitudes of the North and South Atlantic, the North and South Pacific, and the Indian Ocean. Water is returned from the land area to the sea by rivers.
Source: Ambio 1977:1

The simplified scheme of Fig. 2:1b generalizes the main processes and the general water balance of the basin when applying an aggregated view to the basin as a whole. In the upper parts of the basin terrain, the non-evaporated part of the precipitation is transformed into rapid surface runoff, into soil moisture for the vegetation, and into groundwater. In the soil, the water moves more or less downwards. In the lower parts of the terrain, on the other hand, the water movement is considered to be generally upwards, recharging wetlands and other moist parts of the landscape from below.

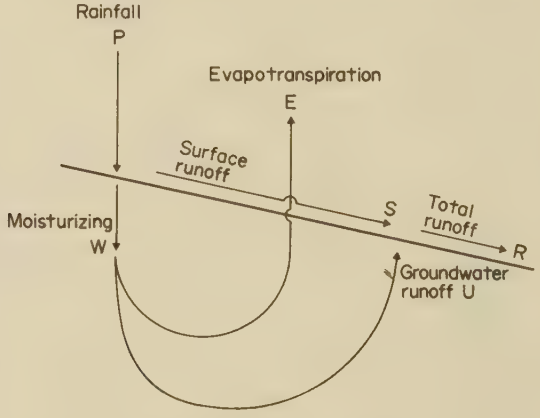


Fig. 2.1b. The general water balance of the river basin when applying an aggregated view to the basin as a whole.
P = precipitation to the basin
S = surface runoff
W = moisturization of the soil by infiltrating water
E_a = actual evaporation and transpiration
U = groundwater formation, later forming groundwater outflow
R = total river flow
E_{pot} = water need of vegetation by optimal water supply conditions

WATER AVAILABILITY

(1) Water Assesement

All water management has to have assessment of the resource as its starting point, although this has not always been fully realized. Consequently, the importance of water assessment was heavily stressed by the United Nations Water Conference 1977 in Mar del Plata, Argentina (UN 1977a). Water resource assessment should—according to a recent definition by WMO—be understood as "the determination of the sources, extent, dependability, and quality characteristics of water resources, on which is based an evaluation of the possibilities for their utilization and control".

In water resources planning, water demands have to be matched to water availability. Here, one has to distinguish between two main types of availability: water availability for vegetation and water availability for satisfying human needs.

Water availability for plant production is characterized by the amount of water available in the root zone. Water that can be made available for water withdrawal can be found either in the groundwater aquifers, or in the drainage network of the rivers.

(2) Availability for Plant Production

(a) Development of the availability concept

The root system of tropical species seems to be well adapted to the conditions of the local hydrological cycle (Balek 1977). Tropical grasses have thus a very dense root system extending into the unsaturated zone. A study of tree roots indicates the presence of a secondary system, reaching the saturated zone. The amount of water stored by capillary forces in the pores between the soil grains in the root zone constitutes the water available for plant production for shallow-rooted species. It is recharged by the moistening of the soil. The size of the storage available in the unsaturated zone is given by the amount of water available within a certain pressure interval relevant from the viewpoint of the species under consideration. The limits of this interval are often for simplicity referred to as field capacity and wilting point. The availability could probably best be approximated as the annual renewal of the two storages referred to, or, more simply, as the annual moisturization (W) (global distribution see Fig. 2:2).

The amount of rainfall infiltrated primarily depends on the characteristics of the rainfall and of the soil cover together with the relief. When the relief is steep and the infiltration capacity low, a large part of the precipitation is drained rapidly as surface runoff (S), forming flood flow in the rivers. The surface runoff can be seen as a loss from the ecological viewpoint, but is important as a factor causing erosion and loss of fertile soil.

Quite often the water available for plant production is, however, taken as equal to the rainfall, and plant production is discussed in terms of meteorology and biology. This implies that the loss constituted by the surface runoff is not taken into account. It is evident, therefore, that the essential role played by hydrological processes necessitates the further development of more correct concepts for availability of water to plants.

(b) Water deficit and water surplus

Water availability for plant production is thus represented by the infiltration into the soil. The water demands of the vegetation is often indicated by the potential evapotranspiration (E_{pot}) under the given climatic conditions. The degree to which the moistening (W) is large enough to satisfy this need can be seen by comparing W and E_{pot}.

Water surplus and deficit from the plant production aspect have, however, often been calculated simply as the difference between potential evapotranspiration and rainfall (e.g. Korzoun *et al.* 1978, Chaturvedi 1976). The approximated *global pattern* of water deficit and water surplus is shown in Fig. 2:3 (Korzoun *et al.* 1978). Although oversimplifying, this map gives quite a clear visual impression of the very large differences in growing conditions between the temperate zone and the tropics where many developing countries are situated. In large areas, the water deficit in fact exceeds 1,000 mm/yr. If allowance is made for the loss by surface runoff the deficit increases further. The size of the deficit gives an idea of the global importance of irrigation, and a first approximation of irrigation needs.

A closer look into the conditions in Africa reveals that only a small fraction of the continent has in fact adequate rainfall for optimal growth during all the months of the year (long-term average conditions). This again shows the importance of irrigation for increasing agricultural production of this continent.

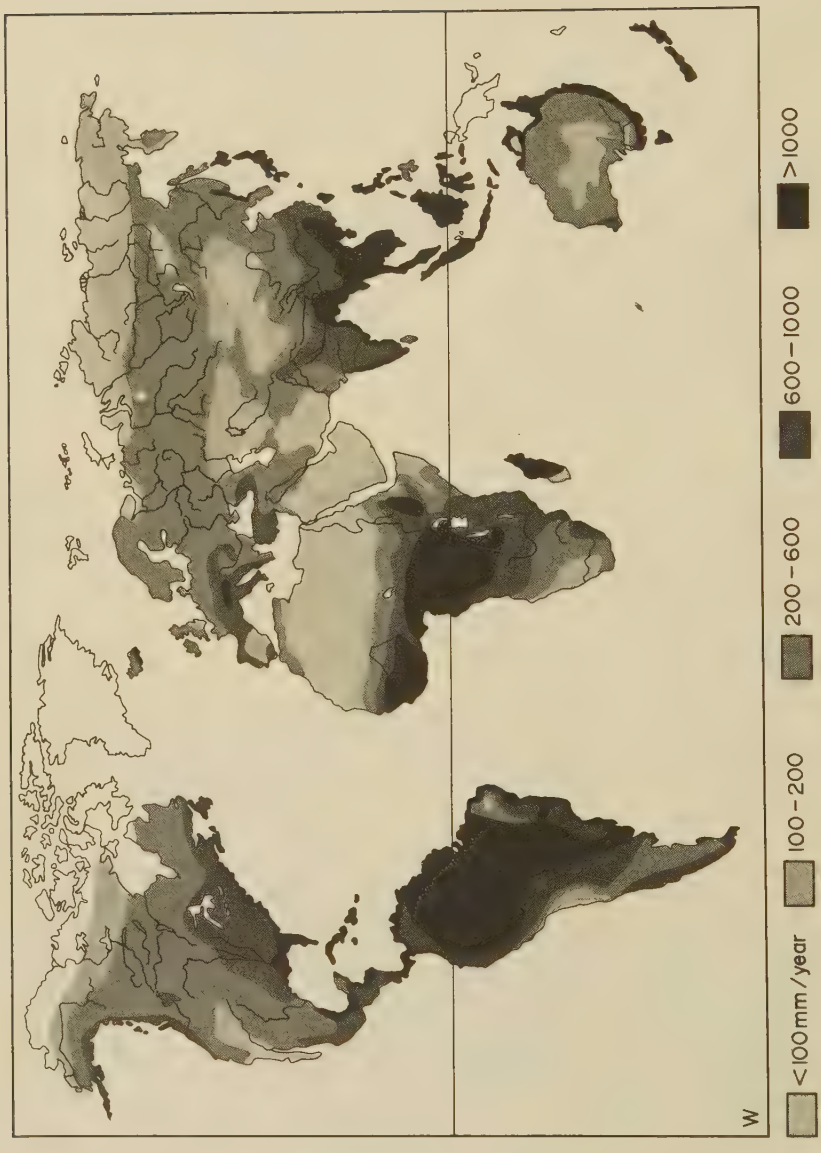


Fig. 2.2. Global pattern of moisturization of the soil by infiltration. Unit: mm/year. In total, 14% of the infiltrated water percolates downwards to form groundwater, whereas 86% is spent through evaporation and transpiration. From Lvovich 1977. Source: Ambio 1977:1

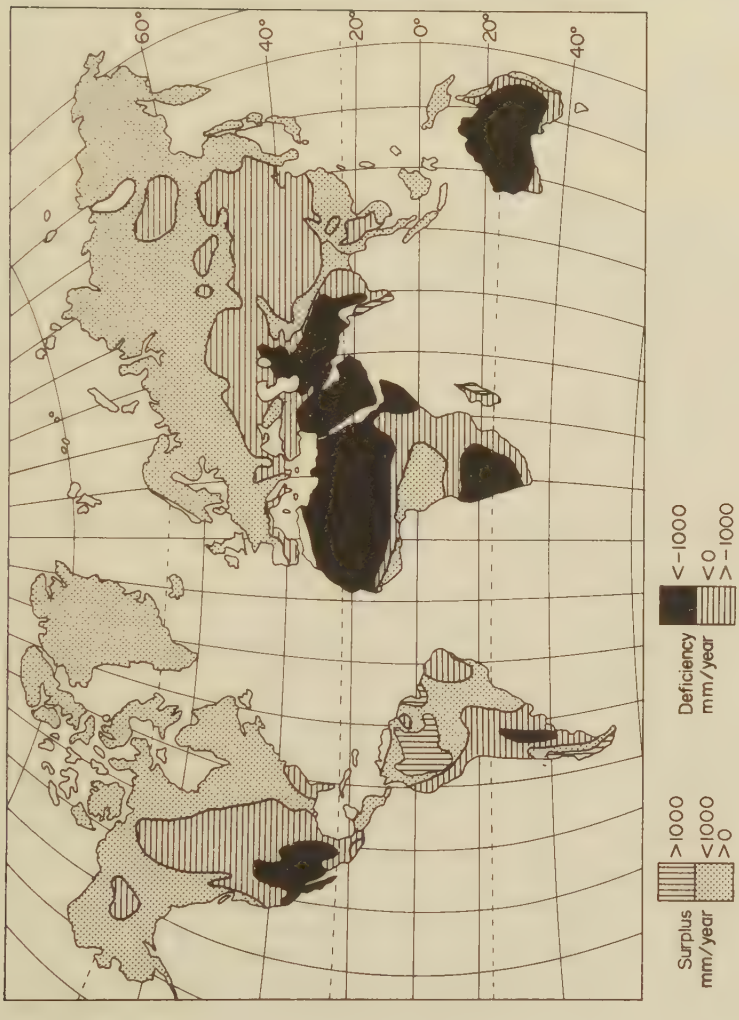


Fig. 2.3. Water-deficiency (-) and water-surplus (+) zones in the world. A water deficiency exists if precipitation supplies less water than would be needed for well-watered vegetation. In the reverse circumstances there is a water surplus. From Falkenmark and Lindh 1974.

In India, a large part of the subcontinent, especially the part situated in the rain shelter behind the Western Ghats, is subject to water deficit conditions during all the months of the year (Chaturvedi 1976).

Even if the hydrological processes in the tropics are the same as in temperate regions, many influencing factors, such as interception, different time and space distribution of rainfall, soil conditions, and the great influence of swamps, act differently. Therefore, one cannot possibly expect that formulae and routines developed for temperate conditions would be directly applicable in solving hydrological problems in the tropics (Balek 1977).

The effect of even small changes in water availability for plant production may be almost dramatic, due to the dominant role played by water in controlling the plant species. Catchment studies in Kenya, for instance, indicate that it is impossible to adapt any general conclusions on the role of the soil before an actual measurement has been provided.

Water is also basic in ecological classifications and the emerging type of combination of grass, woodland and bush is the response to the local water-availability conditions. Savanna signalizes the amount of water stored by degree of greenness by differentiating between grass savanna, shrub savanna, tree savanna, and savanna woodland. Trees, on the other hand, can adapt themselves to very variable availability conditions, and observations reported by Balek (1977) indicate that during the dry season the trees get additional water from the groundwater. In effect,the amount of water transpired from a tropical catchment during a dry year may exceed the precipitation for that year by the bridging role played by groundwater in storing water surplus from earlier years.

On a regional scale, the boundary areas of water deficit from areas of water surplus seem to have a clear ecological implication in that they approximately coincide with the forest-savanna boundary (Davies and Robinson 1969).

To be rough, one could therefore refer to two basic hydro-ecosystems in tropical Africa: humid tropics, and arid tropics. In a more complete classification, one can differentiate between systems with water deficiency under dry conditions (perennially under-watered regions with desert or semi-desert), systems with water excess under wet conditions (perennially well-watered regions with rainforests, perennial swamps and great lakes), and systems with combined effect of wet and dry conditions (seasonally well-watered regions with savanna dry forests and seasonal swamps). There are numerous gaps of knowledge in this area as to the interaction between plant and water in tropical ecosystems. The water processes in the non-saturated zone, including the root systems and the interplay with the groundwater in the saturated zone therefore present themselves as research areas of high priority. In order to find ways for a more economic use of the available water in plant production increased studies should be conducted on methods by which the root systems and their efficiency could be increased by plant improvement, and by technical measures to control growing conditions. Of special interest are physiological studies on the water-economy of different species and types. Water-economy should be used as a criterion already in selecting the crop. Rice cultivation, for instance, implies a major waste of water; there is considerable opposition to exchange it for wheat in water deficiency areas. Also types with differences in water-economy within the same species need to be studied.

In summary, the whole complex of the role of soil water for plant production in tropical systems seems to be of central importance for the process of developing improved food production in the tropics.

(c) Irrigation

Water availability in the soil can be controlled by irrigation, which should be seen as a measure to increase the dependability of soil water and to reduce the risk of this storage being exhausted. Irrigation can take different forms. It can be implemented with internal water as is the case within dry-land farming (rainfed agriculture). Irrigation can then be seen as a recycling of temporary surplus water which is harvested and stored in a tank close to the field. This is evidently a form of local water conservation. Irrigation can also be made with external water transferred from a nearby river in irrigation channels, or from groundwater wells.

(3) Availability for Withdrawal

(a) Groundwater availability

The most important source of water in arid and semi-arid areas is subsurface water. Three types of factors determine the groundwater formation: climatic conditions, morphological factors, and geologic conditions. On a regional scale, the potential availability of groundwater could be approximated by the annual — or rather the long-term — recharge of the aquifers in the region, i.e. the groundwater formation.

Some forms of relief are more favourable than others to the infiltration of rain water. High mountain ranges or isolated massifs, for instance, receive large amounts of rainfall due to their altitude, and their geology often promotes infiltration (UN 1973).

When infiltration capacity is high and the relief flat, a large part of the precipitation may infiltrate. What part of the infiltration will be free to percolate down to the soil profile and used in the recharge of the groundwater depends on the characteristics of the vegetation (root depth, root development etc.), the amount stored in the soil and available for vegetation (water available for plant growth), and the permeability of the soil when saturated with water.

In steppes and dry savannas, the potential evapotranspiration has a dominating influence on the amount remaining for percolation. There is no infiltration during the dry season, but during the wet season surplus rainfall might be available for groundwater formation. In areas where the annual rainfall is below 250 mm/yr, the violence of the rainfall is of central importance and percolation often takes place when the daily rainfall exceeds the daily evapotranspiration.

The global distribution of groundwater formation has been approximated from the amount of groundwater discharged into rivers, cf. Fig. 2:4 (Lvovich 1974), thereby neglecting the relatively small amount passing lower horizons, and therefore not drained by rivers. It is evident that only in certain especially favoured areas is the annual groundwater formation comparable to the conditions prevailing in the Scandinavian region, where it is in the order of 100-200 mm/yr. In the African region, comparable conditions are to be found only on the West-African tip, in the humid tropics and in the source area of the Blue Nile. As for the Indian subcontinent, such conditions only exist along the West Coast, i.e. on the western side of the mountain ridge known as the Western Ghats. In all other areas the *groundwater formation* is substantially lower than in most parts of Scandinavia.

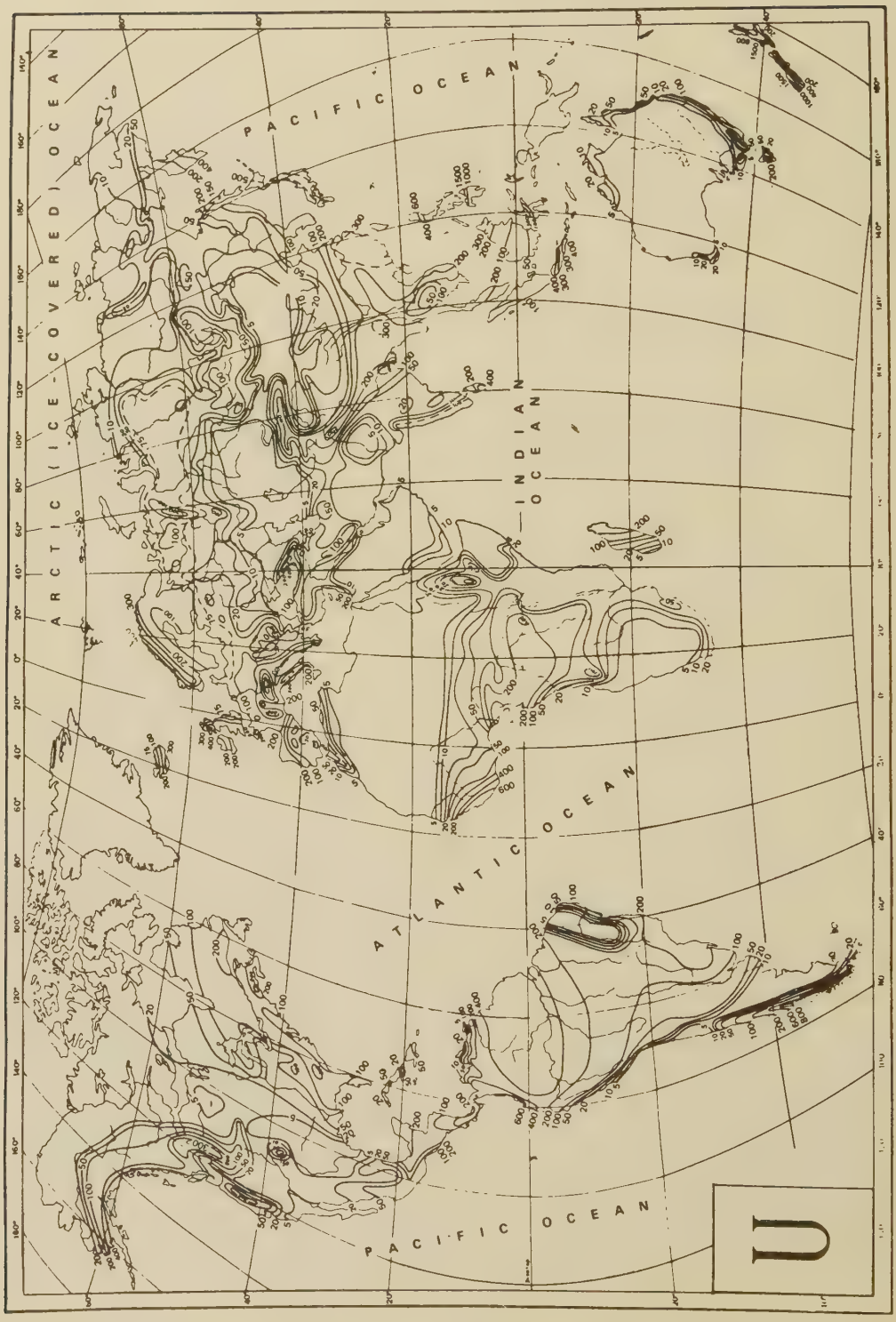


Fig. 2.4. Pattern of global groundwater formation as calculated from groundwater discharge into rivers. Unit: mm/year. From Lvovich 1974.

The *subsurface flow of groundwater* is determined by gravity and the water moves from areas of inflow to areas of outflow. In the latter, groundwater seepage takes place. In general, the flow pattern of groundwater is determined by the transmissivity of the different geological formations. The groundwater primarily finds its way through layers of high transmissivity (aquifers), where the groundwater flow is larger than in formations of low transmissivity.

In tropical basins, it is often wise to distinguish shallow groundwater aquifers from deep aquifers due, for example, to differences in practical accessibility. Shallow groundwater may be found in riverbeds, intermittent swamp and sandy aquifers underlain by impervious layers (Balek 1977). Wells in this groundwater may indicate a higher degree of sensibility towards the precipitation regime with a quick rise soon after the rainy season has started. The aquifer remains saturated until the end of the rainy season; in these aquifers recharge by surface-water infiltration may dominate over rainfall percolation.

Deep aquifers have a slower response to the onset of the rainy season and the water level may continue to rise, sometimes even until the end of the rainy season. The time pattern (regime) of the groundwater level differs even in seemingly orographically uniform areas due to differences in water loss by the tropical vegetation.

In Africa, areas favourable for groundwater formation are, in summary, sedimentary basins in coastal regions, vast permeable formations in the African interior, areas of permeable outcrops and fractured localities of basement regions.

In India, the main geohydrological units are the hard rock areas — until now mainly utilized through large open wells — the alluvial terrains of the Indo-Gangetic plains (claimed to form one of the richest water-bearing formations of the world, extending below 150 m.), alluvial formations in South India as narrow belts along the coast, and consolidated sediment formations in some parts of Rajasthan and Gujarat with aquifers of limited extent occurring between 100 and 150 metres (Dakshinamurti *et al.* 1973).

In India, the groundwater formation has been systematically assessed on the basis of rainfall infiltration to the groundwater body and the contribution of seepage from canals, ponds, tanks, etc., to the recharge (Dakshinamurti *et al.* 1973). The groundwater recharge has been regarded as net recharge when groundwater losses by evapotranspiration and subsurface flow have been subtracted from the total recharge. One might, of course, note that both the evapotranspiration losses and the outflow to rivers might be used by pumping, thus lowering the groundwater level. The losses by deep subsurface flow are, however, not possible to utilize. It might also be added that some of the evaporation losses originate from the vegetational production and are therefore useful, although not available for withdrawal.

Hundreds of millions of people in the tropical and subtropical regions live in areas where igneous and/or metamorphic rocks crop out or lie close to the ground surface, covered only by a thin layer of superficial deposits. Hard rock groundwater and how it should be investigated, assessed and developed has been subject to a thorough study within the International Hydrological Programme (IHP), and a state-of-the-art report is being published (UNESCO 1979).

Vast, deep aquifers of the arid region are artesian, i.e. the groundwater is confined below a non-permeable layer. The special pressure conditions created are determined by the difference between the altitude of the recharge area and that of the discharge area. Much has already been written about the deep aquifers beneath the Sahara. However, much still remains to be done before the mechanisms of the groundwater movement are fully understood. In fact, our first knowledge

of the systems was achieved as a by-product of the oil-prospecting activities in the area. The water under the Sahara exists in seven major basins, acting as virtually closed hydrological systems (Ambroggi 1966). The total recharge of these systems, which takes place at the edge of the desert and in the mountain massifs in its centre, is estimated to be as low as 4 km^3/yr, and their total capacity to be 15,000 km^3. This means that it would take nearly 4,000 years at the present rate of recharge to fill these formations. Only two of the basins have such characteristics that the discharging groundwater is considered to be of recent origin (Great Eastern Erg and Niger basin) with their natural recharge estimated to be 900 and 300 million m^3/yr respectively.

In the remaining five aquifers, water movement is so slow that it should take the infiltrated water several millennia to reach the natural discharge areas. This means that the water emerging today was infiltrated during the time of the Roman Empire or earlier.

(a) Groundwater assessment

In order to assure a groundwater supply on a continuous basis, i.e., to avoid mining of a groundwater aquifer, the withdrawal should be confined to the net natural recharge of the aquifer. If the withdrawal exceeds this amount, mining takes place and the groundwater table will fall to lower levels. Provident planning of water supply based on non-artesian groundwater therefore necessitates an investigation of the exact recharge rate.

Basically, groundwater assessment comprises two types of measures: to assess the areal groundwater formation that constitutes the potential groundwater resources of the area, and to determine where or in what aquifer this groundwater could best be harvested. The former, which is a task for hydrologists, can be performed in different ways. The groundwater formation taking place in the inflow area can be calculated from the rainfall, and the losses by evapotranspiration and surface flow; if the inflow area has to be subdivided in subareas with different soil and vegetation conditions, mathematical modelling may be helpful (Jansson and Zucchetto 1978). The recharge of a certain aquifer can also be determined from the water balance of the aquifer. Conclusions can also be drawn from the age of the groundwater using radioactive isotopes as tracers. Studies on the configurations of aquifers, on the other hand, are mainly of geological character and include hydrogeological mapping and geophysical exploration methods. The amount of groundwater that can safely be extracted in a certain place is determined by pump-tests. Groundwater models form a helpful tool in the determination of water balance and drawdowns of aquifers, including deep aquifers such as the large Saharan aquifers (Gischler 1976).

Acceptable groundwater withdrawal under artesian conditions is a more controversial issue (Ambroggi 1966). Some consider it necessary to keep the artesian pressure high enough to ensure natural discharge without pumping. Others claim that it would be profitable to use up the artesian pressure, so that the pressure head is lowered to a level such that the evaporation losses are fully eliminated, thereby gaining water for human use. Under natural conditions evaporation operates as a huge pump affecting the groundwater down to at least 20 metres below the ground surface. It has even been stated that evaporation in the Sahara probably accounts for the largest discharge from the aquifers. The evaporation losses are largest in the vast depressions, forming outflow regions known as "shotts" in the desert. The large losses are supported by Peixoto's study on atmospheric moisture convergence, which indicates in the Sahara areas a net water input to the atmosphere (Peixoto 1977).

The UN Water Conference discussions were based on the assumption that groundwater assessment should be attained in all countries by year 2000, the documentation including an appraisal of the work needed and the costs (UN 1977b).

(b) Surface water availability

Dependable flow. Surface water is available in the streams but is subject to seasonal fluctuations in response to climatic seasonality on one hand, and to natural possibilities to compensate by subsurface and surface storage facilities on the other. In general, the river flow is constituted by a direct runoff from rain and a delayed runoff from subsurface water and water otherwise stored. The main river regimes are shown on the global map in Fig. 2:5.

The seasonal flow variations, and therefore the dependable flow, are quite different in small and large rivers due to differences in natural storage facilities. In small rivers it is mainly a question of groundwater storage, whereas in large rivers water may be stored in the upstream river channel and sometimes also on great floodplains. Fig. 2:6 shows characteristic duration curves for some different ecological conditions in tropical Africa according to Balek (1977).

Dry weather streamflows are evidently very limited in East Africa (Lundgren, ed., 1975). In India, only rivers in the Himalayan region are classified as perennial, being fed by melting snow in late winter and summer and by rainfall during monsoon seasons, whereas even in the larger rivers of peninsular India the winter runoff is very low.

In small river basins, the direct runoff from the rains passes quickly (Ledger 1969). In large rivers without extensive flood-plains, the flow responds to smaller tributaries. The discharge, therefore, falls rapidly when the wet season has ended, depending however on the available channel storage. In West Africa, base flows may exceed 1 litre per second and square kilometre only in catchments entirely within areas of high rainfall and permeable subsoil (Ledger 1969). In rivers with their basins outside such areas, there is little, if any, base flow. Significant flow beyond the third dry season month occurs only in rivers substantially affected by groundwater and floodplain storage. In large rivers with vast floodplains the conditions are much more favourable. If the gradients are feeble, the flood water causes overflow into adjacent parts of the floodplain and huge, shallow lakes are created. Even if large amounts of water are lost through evaporation and seepage, much water returns to the river when the rains have ceased. This flattens and elongates the flood wave of the hydrograph. The period of low base flow is diminished and the amount of dry weather flow increased.

Surface water assessment. Under semi-arid conditions "the possibilities of providing even modest supplies of river water throughout the dry season depend, over very large areas, upon the feasibility of providing adequate reservoir facilities at an economic cost" (Ledger 1969).

The potentially available amount of surface water can, as a first approximation, be seen as the long-term average runoff, as this amount could in principle be made available all year round by introducing adequate storage facilities either in surface reservoirs or by subsurface storage. However, to reach this storage, technical, social and economical prerequisites have to exist. Surface storage is, for instance, limited not only by topographical and land use conditions but also by the evaporation loss taking place from the reservoirs. The limit is reached at the storage beyond which the marginal gain in dependable runoff is balanced by the marginal loss by evaporation (Wollman and Bonem 1971).

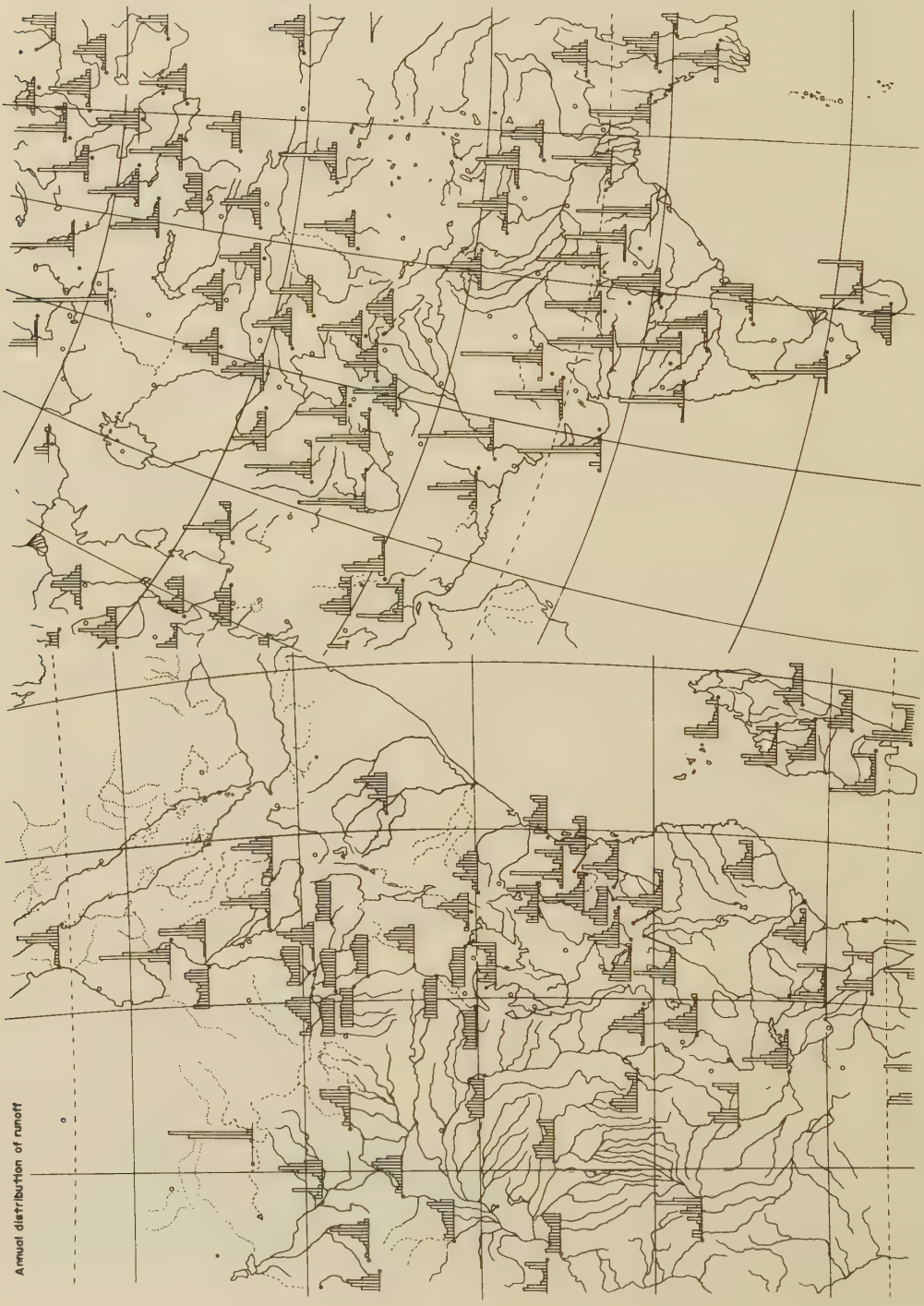


Fig. 2.5. Seasonal variations of river runoff in East Africa and India. From Korzoun (ed.) 1978.

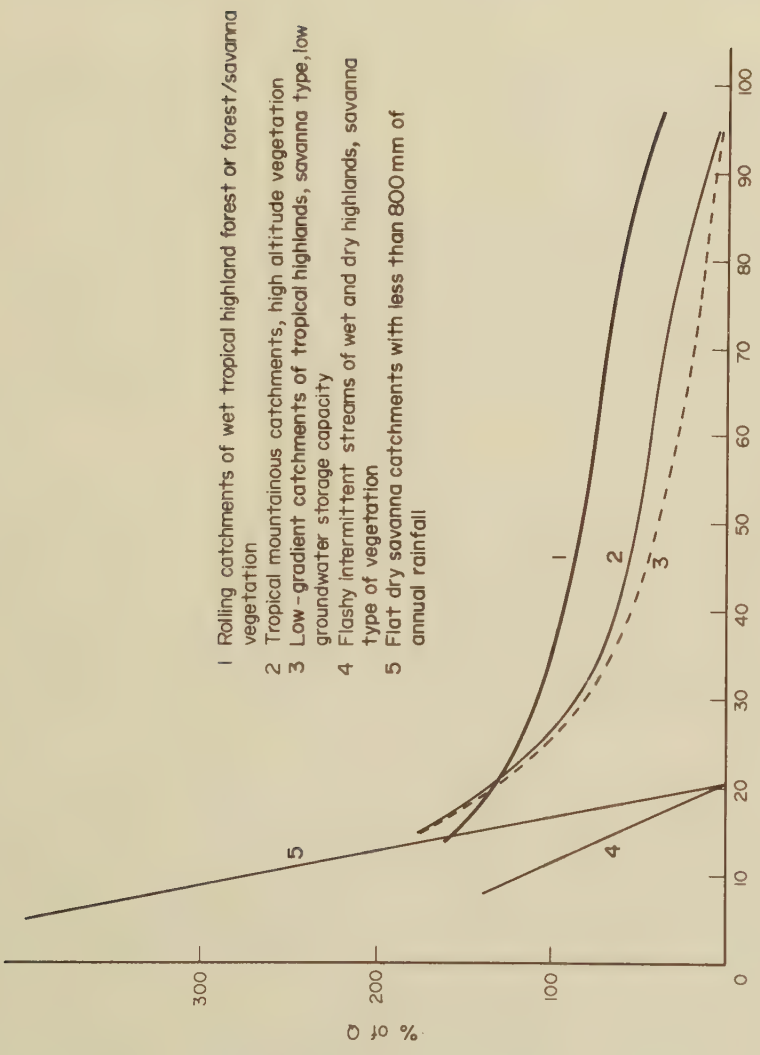


Fig. 2.6. Characteristic duration curves for river runoff for different topographic and vegetational conditions. From Balek 1977.

The conventional way of determining surface water availability is by hydrometric measurements of river discharge by flow measurements (see, for instance, WMO Hydrometeorological Guide). Due to the large interannual fluctuations this has to be extended over a sequence of years in order to provide an idea of the seasonal and interannual variability, and to constitute a basis for a good estimate of the long-term average, and of the dependable flow. According to the documentations of the UN Water Conference, hydrometrical networks are at present far too scarce in relation to the importance of such data for water resources development (UN 1977b). The need to intensify this very basic infrastructural work was, therefore, strongly stressed by the Conference (UN 1977a).

In areas where hydrometric data are scarce, river runoff might be estimated from climatic data and the drainage pattern. Calculations of areal runoff formation are thus based on data on the rainfall and calculation of the losses by evapotranspiration.

In areas where even precipitation data are missing, the areal runoff formation can, as a first approximation, be obtained by studying the pattern of surplus of water from the atmospheric convergence moisture (Peixoto 1977). The existence of large local gradients in some areas would for instance suggest that "excess precipitation in regions of strong convergence could be tapped for irrigational purposes in adjacent regions where there is a water deficit" (citation from Peixoto *et al.* by Davies and Robinson 1969). Although this method opens interesting possibilities for regional estimations, it is still subject to quite large imperfections, mainly due to the great errors involved in interpolating the wind field from a very scarce network of wind stations.

(4) Some Main Gaps of Knowledge

The water-availability field suffers from numerous gaps of knowledge. In the past, little emphasis has been given to collection and research of water resources data in large parts of the tropics. The reason is evident: data collection on water presents no immediate benefit—the activity gains its value first in the long run when the data base starts to reveal the size of natural fluctuations with a successively increasing degree of certainty. Missing data implies missing information, not only on the size of the water resources but also on the hydrological processes as such, and leaves the countries of the tropics with equations and thumb rules developed in other climatic surroundings.

The UN Water Conference accepted as a goal that water resources should be assessed in all countries by the year 2000. This leaves us with some 20 years for the necessary data collection. WMO and UNESCO/IHP have taken the lead on this subject and are developing frameworks for network planning as well as assessment methodology. Whereas data collection should be seen as a routine activity, the closer analysis of the interdependencies between different hydrological processes and between hydrological phenomena and landscape factors should be seen as important research tasks that have to be undertaken in all countries. One aim is to see the extent to which rules developed under other climatic conditions hold for tropical conditions. There are also other evident reasons: knowledge of the operation of the catchment and its different subsurface water storages, and its response to precipitation events, constitutes a basic tool for developing both river-basin management and adequate methods for environmental impact assessment. Models have to be developed for typical environments also in order to make possible water-resources assessment in areas when data are scarce or even missing. Research basins, representing different types of landscape should be seen as an important tool in developing such models. In particular, the special hydrology of landscape features typical for the tropical zone, such as tropical swamps, needs to be looked into.

Information on soil water and the possibilities of managing it constitutes another area of great concern. Also here, the fluctuations are important and the approach taken by ICRISAT should be strongly supported and expanded to other relevant soils and climatic regions. The manageability of the water use of different crops probably constitutes one of the most important issues to be approached.

SHORT-TERM AND LONG-TERM VARIABILITY

(1) Water Seasonality and Human Distress

Seasonality of water supplies constitutes a major problem in daily life in large parts of Africa and southern Asia. The bias constituted by differences in climate makes it difficult for western people to understand the importance of such fluctuations and the degree to which they influence the daily life in developing countries. Seasonality is closely correlated with health.

> "While care is needed in generalising, the evidence suggested that for agriculturalists in the tropics, the worst times of year are the wet seasons, typically marked by a concurrence of food shortages, high demands for agricultural work, high exposure to infection especially diarrhoea, malaria, and skin diseases, loss of body weight, low birth weights, high neonatal mortality, poor child care, malnutrition, sickness and indebtedness." (Chambers 1978a).

A strong seasonality implies that during the dry season when local tanks and water holes have dried out, people are more dependent on wells or rivers for water. Most small rivers also dry out after some time, which leaves only the larger rivers as possible surface-water sources. Increasing distance to water sources severely increases the water collection burden of women and children.

(2) Monsoon Fluctuations

A region depending on the timely arrival of the monsoon for crop production is especially vulnerable to great variations of the temporal distribution of rainfall during the year.

Figure 2:7 illustrates the interrelations between rainfall and cultivation of millet. Both very heavy rainfalls and too little rain may be deleterious to crop growth. In India, the crucial months for agriculture are July and August, and the success of the rain-fed *kharif* crop depends on the distribution and amount of rainfall during these months in particular (Michael 1978). The pattern of crop production is greatly determined by the onset and withdrawal of the monsoon. Effects of fluctuations are most heavily felt in northern India where the monsoon lasts only 1½ months as compared to 6 months in the southern parts.

In both Africa and India, the regions most prone to drought are the zones at the northern edge of the monsoon's range. Not only do they have variable weather from year to year, but they are also the first to suffer when climate changes appear. They could, therefore, be seen as climatic borderlands, or ecotones (Bryson and Murray 1977). The Sahel region is subject to a mixture of two different rainfall patterns, emanating from two alternating circulation patterns: relatively wet conditions when the intertropical convergence zone penetrates sufficiently far northward and relatively dry conditions otherwise.

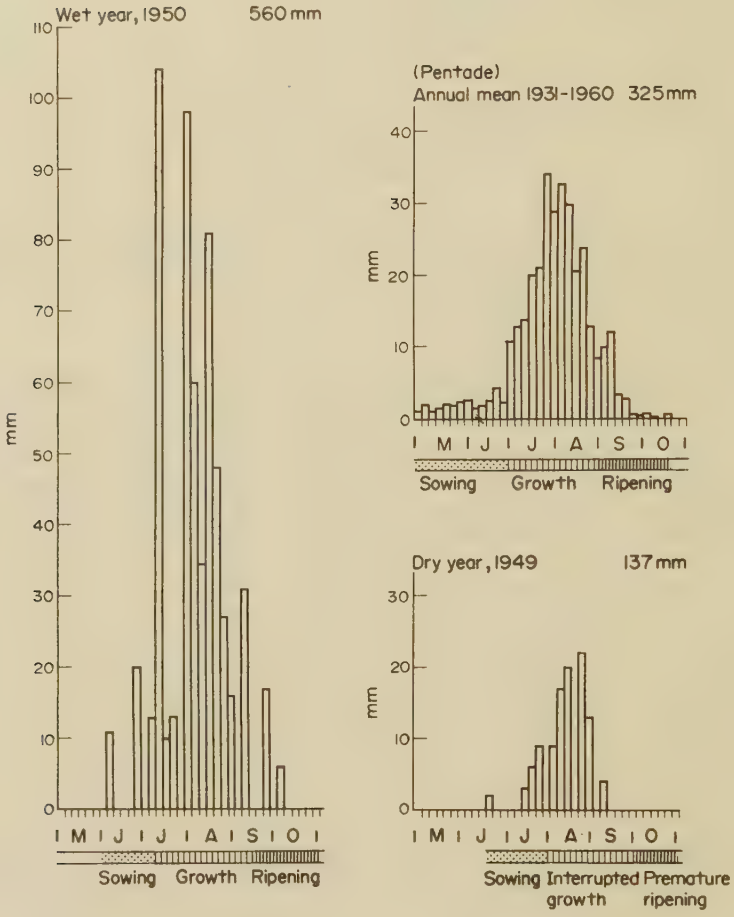


Fig. 2.7. Cultivation depends strongly on precipitation conditions. Figure shows variability of precipitation and millet cultivation in Northern Darfur. From Mensching and Ibrahim 1977.

In India, rainfall is primarily dependent on the monsoons and to a certain extent on shallow cyclonic depressions and disturbances (Chaturvedi 1976). The variability is extremely important as deficiencies during critical periods of crop growth may be disastrous. Even during the monsoon the rainfall is most uncertain. This makes rainfall frequency and probability analysis very useful in planning cropping patterns and irrigation requirements. "The variation of the rainfall from the 'normal' is more important than the normal value itself" (Dakshinamurti *et al.* 1973).

(3) Fluctuations of Annual Rainfall

(a) Rainfall dependability

A rainfall seasonality with 2-4½ months of rainfall is typical for the semi-arid tropics, but the pattern of seasonal rainfall may vary considerably from year to year (Fig. 2:8). Rainfall dependability has considerable relevance to the possible risks of crop failure in agricultural production, and may be expressed as a probability for rainfall; a 70 per cent probability would then mean that a farmer would get 7 yields out of 10.

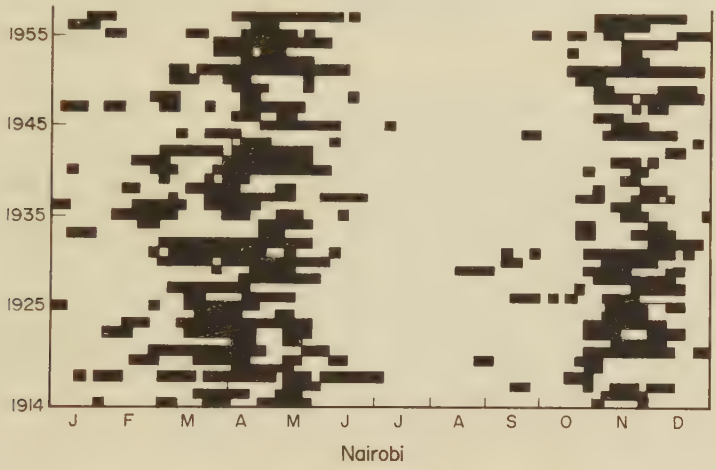


Fig. 2.8. Interannual variability as illustrated by rainy 5-day-periods (black) during the period 1914-57 for Nairobi. From Jackson 1977.

In India, rainfall probability studies have been carried out at ICRISAT in a study of differences between 56 locations (Virmani *et al.* 1978). The probabilities are estimated both as probability of rainfall during a certain week (initial probability) and probability of rainfall during the following week, if the present week has been wet or dry (conditional rainfall). In fact, differences in dependability during certain key periods of crop production could explain observed differences in yield conditions in localities of very similar conditions. ICRISAT intends to expand their studies to other parts of the semi-arid tropics.

There are considerable differences in dependability between areas. The impact of rainfall variability is considerable, especially in view of different feed-back and time-lag effects caused by social, economic and cultural factors (see, for instance, Gustafsson 1977). There seems to be a general tendency towards higher variability in areas with lower rainfall (Morales 1977), but numerous warnings have been raised against too sweeping generalizations. It has even been suggested that the observation of greater variability could, in fact, to some degree be a question of perception rather than geophysical facts as fluctuations in supply are bound to attract more attention under water-scarcity conditions.

Due to scarce data and to differences in sampling periods at different stations, existing variability maps may also be very inaccurate (Gregory 1969). Rainfall variability is displayed in terms of mean or standard deviation of annual rainfall, thereby tacitly assuming that rainfall follows a normal frequency distribution. However, in arid and semi-arid regions, rainfall data often are characterized by a marked positive skewness (Katz and Glantz 1977), which makes the variability measure chosen inexact.

(b) Some misleading concepts

Rainfall statistics are often presented in terms of monthly or annual averages. This is very misleading, as pointed out already in 1958 (Worthington in Gregory 1969), as it may create a tendency to neglect the very important implications of large rainfall fluctuations. The great time-lag in developing parameters better adapted to semi-arid conditions may, in fact, be due to climatic bias, the basic concepts being developed by meteorologists from other, better endowed regions.

A further point well worth stressing is of more semantic origin: there is frequent use of the concept *normal* when discussing long-term average rainfall. In fact, an incessant use of this concept might contribute to the seemingly slow acceptance of seeing large rainfall fluctuations, and therefore also intermittent droughts, as part of the climatic pattern that is normal for these regions. Even if the meteorologists themselves are perfectly aware of the meaning of the concept *normal*, the perceived meaning among other groups of society may be quite misleading (Katz and Glantz 1977). One has to be aware of a tendency to understand the concept *normal* as "a normative quantity like the temperature of the human body, with its connotation that a departure is abnormal" (citation from Landsberg in Katz and Glantz 1977). With this view, when rains return after a multi-year period of drought, they are wrongly taken as a return to normality.

(c) Large-scale atmospheric interconnections

The monsoons governing rainfall conditions in large parts of the tropics are regular features of the atmosphere and a consequence of the interaction between several processes of the global circulation. The monsoons of the northern hemisphere bring moist air to lands between the sea and the intertropical discontinuity (ITD) which is situated close to the zone where the sun is in zenith (Fig. 2:9a). The "burst" of the SW monsoon in India is considered connected to a sudden change of the upper troposphere air-stream from westgoing to eastgoing as the westgoing jet-stream suddenly withdraws from its quasi-permanent winter position south of Himalaya to a position north of this range (Spate and Learmonth 1972).

In June, the intertropical discontinuity has its northernmost position, and the monsoon rains of West and East Africa and India have their largest extension. The exact northern borderline of the monsoon rains in a certain year depends on the large-scale atmospheric circulation due to the tie between the monsoon system and the westerlies and therefore depends on the actual pattern of that wind system (Bryson and Murray 1977). The position of the ITD is critical in that the monsoons cannot penetrate it. The crucial question for both Sahel and for northern India is where the anticyclone deserts separates the westerlies from the ITD.

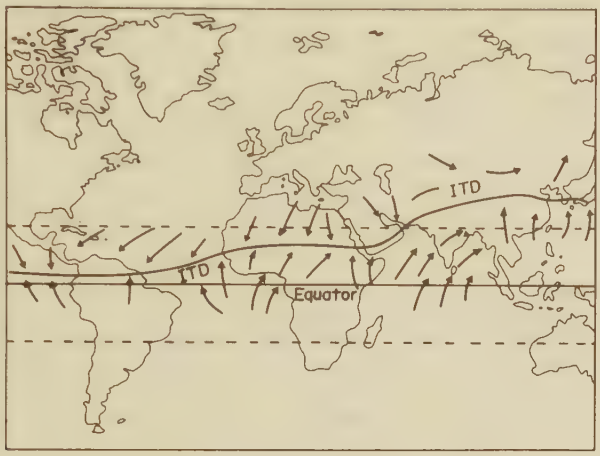


Fig. 2.9. The northern penetration of the intertropical discontinuity determines the monsoon rains. From Bryson and Murray 1977.

a) Typical surface wind pattern in July.
b) Northward penetration of monsoon rains in the Sahel. Drought prevailed 1968-73.

The importance of the westerlies is most dramatically seen in India: the question is *when* and *if* the westerlies in the summer shift to the northern side of Himalaya, because only in that case does the ITD reach so far to the north that northern India gets the regular summer monsoon rains. An expansion during a certain year of the region of arctic air is thus enough to hold the monsoon south during that same year, which means monsoon failure in northern India. Changes in the westerlies may develop in response to changes of both the equator-to-pole temperature difference and the bottom-to-top temperature difference of the atmosphere.

A famous and recent example of weak northward penetration of the monsoon rains is the drought in the beginning of the 1970s which hit both the Sahel region as well as northern India (Fig. 2:9b). The huge difficulties encountered in the Maharashtra region have been comprehensively reported by Subramanian (1975), who studied how certain reactions and measures created major difficulties in the ability to cope with this catastrophe.

(4) Long-term Climatic Trends

(a) Natural and unnatural changes

The difficulty in seeing large rainfall fluctuations as natural features started intensive discussions among scientists as to whether the droughts mentioned above were due to a climatic trend caused by the influence of man, or whether they were an effect of natural fluctuations. The general opinion seems to be that they were basically due to large-scale circulation anomalies of natural origin and, in fact, that they were similar to earlier droughts (Flohn 1977).

The question of the degree to which man's activities might influence the occurrence and severity of future droughts is evidently very important, especially as the problem concerns huge populations in arid and semi-arid areas. It is, for instance, claimed to be quite conceivable that the raised albedo caused by deterioration of surface vegetation may act as a positive feed-back tending to prolong and intensify droughts caused by large-scale atmospheric processes (Hare 1977).

When separating natural climatic fluctuations from man-made long-term climatic trends, a more distinct terminology is needed: Flohn (1977) suggests that the term *climatic change* should preferably be restricted to major long-term changes, such as between an ice-age and a warm interglacial period, whereas *climatic variation* should cover changes between 30-year-averages and *climatic fluctuation* interannual deviations.

According to Flohn, natural phenomena causing climatic fluctuations involve energy inputs or losses of the order of 100-300 TW (volcanic dust from volcanic eruptions, cloudiness changes, El Niño episodes — i.e. ceasing upwelling of cold water close to the South-American west coast — snow-cover variations, arctic sea-ice variations, etc.).

Energy estimates of different kinds of human influences indicate that the major modification would result from large-scale irrigation and reservoirs due to the large increase in evaporation. An additional annual evaporation of 1,000 mm would amount to an annual extra water loss of 2,500 km^3 and input of latent heat to the atmosphere of 150 TW. Inputs from other human activities, even if locally high, at present amount to a total of only 15-20 TW (heat inputs by energy consumption, annual increase of CO_2, tropospheric dust, savanna bush-fires etc.). Flohn concludes that "there is no question that the impact of man on the climatic system has now reached a level near to that of natural climatic fluctuations, and that we are on the fringe of anthropogenic climatic fluctuations on a global or at least hemispheric scale". The over-all result of human activities may be a slight but general warming, "each effect contributing essentially in the same direction". The present increase of continental evaporation taking place due to irrigation and reservoirs may, however, be a recent development reversing the direction of the human influence: a vanished natural vegetation would imply a reduction of evaporation which may have gone on through many centuries: of grasslands by overgrazing, of dry forests by burning and of humid forests by shifting cultivation. The over-all effect of a reduced land evaporation would have made more energy available for direct heating.

(b) Possible future trends

Taking into account the great vulnerability of some of the densest populated areas of the world to climatic changes, the question of possible future consequences to world climate of a continuation of the present trend of increased input of energy is extremely important. There are, however, different opinions on this question.

One opinion is that especially the input of CO_2 might have drastic effects on heating the atmosphere: a continued input increase might at the end of the twenty-first century involve even the disappearance of the arctic ice. This would mean a shift of the large-scale climatic belts of winds and precipitation 300-600 km to the north in the northern hemisphere and, therefore, imply far-reaching consequences for the living conditions in densely populated areas.

Another opinion (Bryson and Murray 1977) is based on the hypothesis of a cooling due to dust-creating activities as burning of fossil fuels, slash-and-burn agriculture, etc. This might result in expanding the westerlies and increasing their looping, implying increased frequency of droughts to monsoon-depending regions such as Sahel and northern India.

Numerous other processes must also be considered. The spreading of oil films over the oceans may be a factor of some importance in that it changes the albedo and therefore the local energy balance. Thus, attention must also be paid to different sea-land interactions (Hare 1977).

The importance of water in the energy balance of the atmosphere introduces a close link between future climatic changes and hydrological processes (Kalinin 1971). A potential global warming would, for instance, imply increasing evaporation, i.e. heat expenditure. Also, huge increases in water consumption, due mainly to large-scale irrigation development all over the world, would result in heat expenditure. The water cycle therefore introduces time-lag components, slowing down any heating process.

The conclusion of Kalinin is that "in this respect, water resources will accrue in a fundamentally new role, as one of the major means of preventing earth overheating". An increased amount of water vapour in the atmosphere is expected to cause increased water recirculation over the continents, i.e. local increase of precipitation.

(5) Conclusions

The problems of poor rainfall dependability, of present droughts and of possible man-caused influences on these phenomena concern huge populations in arid and semi-arid areas. The importance of rainfall dependability for cropping conditions makes it a task of high priority to develop good rainfall statistics, especially for the semi-arid tropics. Continued and expanded research is needed to clarify the links between the relevant atmospheric systems in order to reach better understanding as a base for future forecasts and warnings.

Finally, it seems to be almost an understatement to point out that the climatic fluctuations of the atmosphere, the degree to which human activities influence them and their mutual interrelation with hydrological processes constitute a research area of primary importance. In terms of the time constants involved in the ongoing social and economical development in the developing regions of the world the time spans envisaged in Flohn's visions are not unrealistic.

WATER QUALITY AS AN ASPECT OF AVAILABILITY

For many on-site uses, such as swimming and recreation and uses based on biological production with the aid of water, water quality is a characteristic of basic importance. Consequently, water quality could be regarded as a second dimension of the availability concept.

(1) Use-related Quality

(a) Water quality concept

Although "water quality" is an extensively used term, it is not very well defined. It is often used more or less as an equivalent to "composition of water" or "characteristics of water from the physical, chemical, and biological points of view". The word "quality", however, suggests that some kind of consideration has also been included as to the suitability of the water for a certain use.

Most water uses are connected with specific desires as to the physical, chemical, or biological characteristics of the water, e.g. the maximum (or sometimes the minimum) temperature or content of specific substances in solution or suspension. An adequate quality description has usually to take into account a number of different substances or characteristics, and to combine them into some comprehensive indicator or measure of the resulting suitability for use. The multiplicity of relevant characteristics, however, makes it difficult to express this suitability in simple, numerical terms. Instead, descriptive wordings are often resorted to. Sometimes, the most relevant characteristics are categorized and divided into different classes to make a simple classification possible.

The minimum quality for a certain water use is connected with the desire or necessity to avoid occurrence of certain processes as a consequence of that specific water use. For instance, the biological processes in the living cells of animals and plants make it necessary that the water complies with certain conditions as to salt concentration, temperature, etc. If the salt concentration is too high, reactions based on osmotic pressure relations might run backwards. If the concentration of certain key elements is above certain levels, the reactions desired might be hindered by some toxic effects.

(b) Quality criteria and standards

Quality criteria must, therefore, take into account the conditions that certain kinds of damage are to be prevented, e.g. mechanical damage in turbines during production of hydropower, or chemical poisoning or infectious diseases due to consumption of drinking water, or due to bathing, washing, or recreational activities in natural water (Rodda 1976). The content of pollutants, such as oxidizable organic matter (from sewage or industrial waste water), might be maximized for certain uses, due primarily to its role in using up the oxygen content of the receiving water. Inorganic nutrients (from sewage or from outwash from agricultural lands) might be maximized due to their role in stimulating the growth of algae in reservoirs and lakes.

Table 2:1 summarizes some basic conditions which are to be expressed in the quality criteria for different water uses. The main problems are often to know what exact characteristics and what numerical values of these should be chosen. Few organic chemicals in drinking water have limits based on firm knowledge of the toxicity to man. In other cases, the limits are based on toxicological studies on animals. In many cases, the limits, although more empirically than scientifically based, have proved to be satisfactory during a long period of application.

The World Health Organization has worked out international standards for drinking water to be used as guidelines by governments. The standards include concentrations of different dissolved substances, but also odour, taste, colour, bacteria content, etc. Often, however, the national public health authority has its own water-quality standards. India, for example, has prescribed its own supplementary standards (WHO 1977). Of course, bacterial safety should be seen as the main objective. Physical and chemical characteristics could be seen as secondary objectives. Sometimes, values exceeding the conventional permissible limits for hardness, chlorides, sulphates, and total dissolved solids have to be accepted, especially in areas where the local populations already are adapted to higher values by long usage.

TABLE 2:1

WATER QUALITY IN RELATION TO WATER USAGE

Water use	Quality criteria
Navigation	Free from large masses of floating debris (e.g. vegetation) which may foul propellers, etc.
Power generation (hydroelectric)	As above, to avoid damage to intake structure, plus inert suspended solids limitation to prevent erosion of turbines, etc.
Amenity (appearance and smell only)	Limit on-organic content to prevent anaerobic conditions arising -turbidity to give light penetration for viewing -suspended solids to avoid unsightly deposits -oil, grease or other floating matter which renders the surface unsightly -nutrients to prevent undesirable growth developing
Fishing and amenity (where it is desired also to maintain a healthy aquatic population)	Limit on-organic content to prevent deoxygenation -turbidity to permit plant growth and photosynthesis -suspended solids to avoid damage to the benthic community especially near breeding grounds -oil, grease and other floating matter for effecting recreation capacity -toxic matter which may affect members of the aquatic community in the short or long term -nutrients to prevent undesirable growth occurring which may cause marked diurnal fluctuations in DO or, by altering the nature of the substrate, change the flora and fauna
Recreation (boating)	As for 'Amenity'
Recreation (swimming)	As for 'Amenity', plus limit on faecal contamination to prevent risk of spreading intestinal and cutaneous disease
Irrigation	Limit on salinity to control osmotic pressure and consequent damage to plants; also certain dissolved salts, e.g. borates Limit on faecal contamination to prevent spread of intestinal pathogens via food crops
Industrial supply	Very much dependent on industrial process but the following are some common criteria: Minimum of dissolved oxygen to avoid odours and chemical contamination Limit on-pH range to minimize corrosion -solids to prevent corrosion and deposition and contamination of product -salinity and hardness to minimize scale formations -faecal contamination where food processing is involved
Domestic supply	Limit on-faecal contamination to avoid spreading intestinal diseases -toxic materials to prevent chemical poisoning -substances affecting palatibility such as taste, odour, salinity, colour, turbidity, solids -hardness

Source: Rodda (1976).

In general, the content of water-quality standards would depend on what basic assumption has been made as to the water source. It is, for instance, probable that the standards would list different substances in case the raw water is assumed to be groundwater, well protected from contamination, or surface water, subject to contamination from sewage or industrial pollution. Most conventional drinking water standards were originally based on the assumption that water would be abstracted from groundwater sources or at least from safe uncontaminated surface water sources (Shuval 1977). This implies that the standards do not cover the multiplicity of contaminants which may be found in contaminated rivers. It is today in the industrialized areas still an open question whether "standards (can) be developed to cover the wide range of contaminants that are actually found in waste-water destined for domestic consumption" (Shuval 1977). In vast industrial regions of the world, man seems to have accepted that domestic-water supply implies an unintentional reuse of waste water.

In developing countries, many rivers carry low discharge during part of the year, and seasonality phenomena make people quite dependent on this flow for water supply. The hazard of contaminating rivers by industrial pollution is, therefore, an even more menacing phenomenon than in countries under more favoured climatic conditions where seasonality is less expressed.

(2) Chemical and Biological Characteristics of Natural Water

The chemical characteristics of natural water change continuously during the circulation process due to the interaction between the moving water and its surroundings in the atmosphere, the lithosphere and the biosphere.

Dissolved substances are continuously added to and removed from the water while circulating in the hydrosphere. The rain reaching the ground is a dilute chemical solution. Main sources of dissolved constituents entering the water while passing through layers of soil and fissured rocks are the results of rock weathering. The composition of the solution is continuously modified by chemical reactions, such as ion exchange and chemical precipitation, and by biological processes of plants and organisms. The concentration of substances may be modified by changes in temperature and pressure.

Thus, natural waters vary considerably as to their natural composition not only in space, where it is a function of the chemical history of the water, but also in time where variations in flow, and temperature as well as changing flow origin create different chemical as well as biological conditions. There are large differences both in composition and concentrations in river water between periods of base flow when the water is predominantly groundwater and periods of floods when the river is filled with water that has passed the catchment close to the ground surface.

Some of the quality parameters included in water quality standards, refer to substances which emanate from natural sources within the catchment, others refer to possible pollutants which might have been introduced by man by waste-water disposal. Natural substances included in drinking water standards are, for instance, iron, manganese, fluoride, chloride, total hardness, acidity. Compounds of anthropogenic origin are bacteria and different substances with toxic effects such as cadmium, mercury, lead, nitrate.

Large efforts have been devoted to water quality studies, especially in the temperate region. The classical hydrochemical literature on natural water primarily concerns the chemical processes involved and analytical methods (see for instance U.S. Geological Survey, 1970). Less interest has, up to the present time, been devoted to the dynamic character of water quality. The interplay between

water and catchment and the effects of changes in flow origin is focused, for instance, in Gregory and Walling (1973), who introduced the expression "water quality dynamics". It is interesting to note, however, that there are relatively few studies on water quality dynamics, or on the processes involved in the continuous shift of chemical composition of natural water. In effect, the immense struggle in the industrialized countries against the pollution menace has directed most of the research resources after World War II towards pollutants.

Climatic conditions in the tropics being vastly different from those in the temperate zone, comparative studies on hydrochemical characteristics of natural water in different climatic and geological regions, and on the influence of differences in hydrological regime, would be most welcome.

(3) Role of Water Quality in Transfer of Diseases

The frequent exposure of the human body to water both internally by drinking water and food, and externally by bathing, washing etc. makes water a key agent in the transfer of diseases, and thereby also for human survival.

Much has been written about water quality and health in developing countries and an excellent summary can be found in Feachem *et al.* (1977). The intention here is, therefore, only to give a short review of some relevant facts needed for a full picture of water problems in the development process.

Water-related diseases create a larger hazard in tropical countries than in the cooler environments in the temperate zone (Bradley 1978). The hazards of bad water are in fact much more serious in high temperature areas. The climate constitutes favourable conditions for many infections spread by organisms which need warm temperatures for their development, and which are therefore rare in most temperate lands. Furthermore, the great poverty of the main part of the population in many developing countries impedes a rapid attainment of safe water supplies, and the rapid population growth increases the number of potentially infected individuals. So, this is in fact a question of a vicious circle.

When looking closer into water-related diseases, one has to distinguish between infectious water-related diseases and diseases caused by some chemical property of the water. Examples of water-related, non-infectious diseases are the cardiovascular disease associated with water softness, and infantile cyanosis due to high nitrate levels in the water. Also, high fluoride levels may affect bone growth adversely. In industrialized countries where the abatement of water-related infectious diseases has been very successful, chemically caused diseases are at present attracting greater interest, especially those due to water pollution. For instance, toxic chemicals and heavy metals introduced with waste waters constitute a major health hazard. It suffices here to recall such catastrophes as the *minamata* and the *itai-itai* diseases in Japan in the beginning of the 1970s. As already mentioned, in such circumstances, international water-quality standards do not provide the security they are intended to ensure.

In developing countries, infectious diseases still take a large tribute in terms of human suffering. A noteworthy part of the high morbidity rates among children in tropical developing countries, but also among adults of all ages, is due to water-related diseases, although the exact amount is impossible to estimate. In addition, a large part of the population is subject to diseases which makes them weak and often even apathetic. A certain minimum level of public health evidently constitutes one of the very basic conditions for mobilizing the public interest and participation necessary for a successful process of social and economic development.

Two measures are fundamental in trying to control the spread of infectious diseases: a supply of clean drinking water, and good sanitation.

The understanding of water supply as one of the very basic societal measures in facilitating economic development in an area goes back to the understanding of water-borne diseases as a severe handicap. Some water-borne diseases are, however, spread also by other faecal-oral routes and the success in terms of improved health does not always follow water supply installations. The interrelation between health, water quality, and sanitation needs, therefore, has to be better analysed, and constitutes a research area of high priority.

WATER IN RELATION TO LAND USE

(1) Introduction

We have already noted that within the continental branch of the hydrosphere, water is circulated through nature on a module basis with the river catchment as the general basic unit. The transient nature of water means that the different parts of the water circulation within the basin interact, so that activities affecting earlier phases in the process sequence also affect later phases. In this sequence of hydrological processes, the soil cover and vegetation act as a key zone due to its very central role in the runoff formation process. All land-use changes which imply manipulations with this zone by modifying vegetational cover, foliage density, root depth, soil penetration characteristics, roughness of ground surface etc. would therefore involve potential consequences on the water-flow conditions in different respects.

(2) Man as a Factor in the River Basins

Besides natural factors influencing the hydrological system in a river basin, man should be seen as a factor which may eventually grow to be of major importance. In order to satisfy water-related needs, man claims the right to make *use* of natural water as a water source, as a recipient for waste water, as a source for hydropower production, as a base for boating, for bathing, for fishing, etc. He then claims the right to withdraw a certain quantity of water, or that water quality should hold a certain minimum standard. In order to make the intended use possible, man also claims the right to *interfere* in certain distinct ways with the hydrosphere. He may wish to correct certain imperfections regarding water availability in time and space. He may also carry out different land-based activities which involve manipulations with the runoff formation process. Examples of the former interferences are abstraction arrangements, facilities for flow regulation, sluices, and canals. Examples of effects caused by the latter kind of interferences are altered groundwater formation, increased high water, decreased low water, and changed quality.

These manipulations with both land and water makes man *one of the factors* influencing the water-circulation conditions. The manipulation of the hydrological processes are caused by three categories of anthropogenic measures (Falkenmark 1977), cf. Fig. 2:10.

- water abstraction from rivers and groundwater aquifers, whereafter water is returned either to the atmosphere as evapotranspiration or to the river system as polluted waste water

- in-stream structures to facilitate on-site use and to regulate river flow

- manipulations of the land-soil-vegetation system thereby modifying the groundwater and runoff formation process.

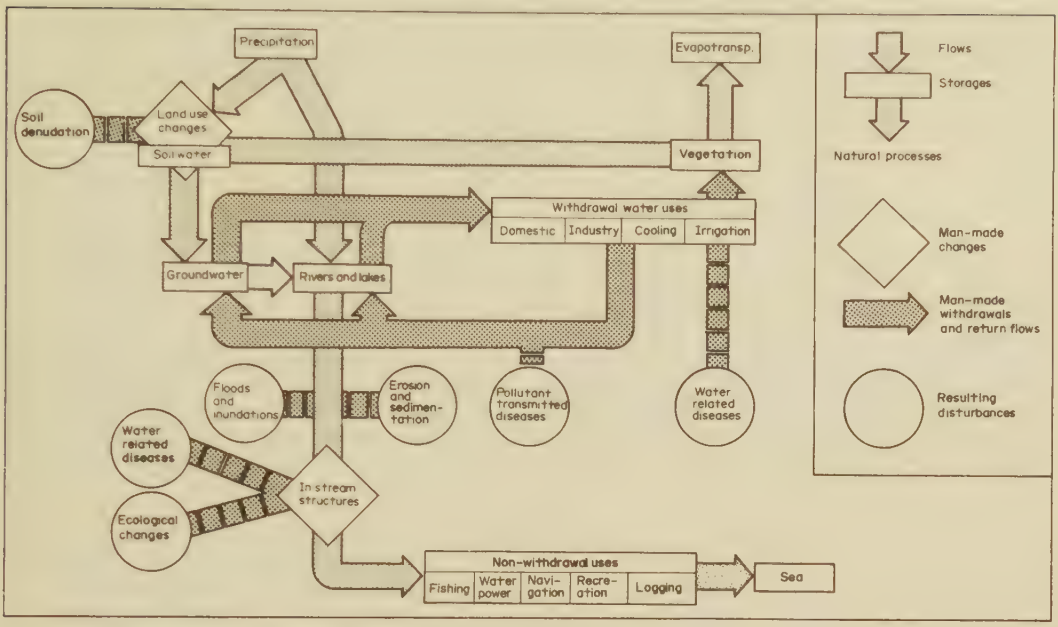


Fig. 2.10. Simplified scheme illustrating man's interaction with water. Water is *abstracted* from its natural course in rivers and groundwater aquifers for water supply of communities, industry, and for irrigation but is also used instream for fishing, hydropower production, recreation and navigation purposes. Man also disturbs the natural system by introducing different *instream structures* to facilitate instream uses or to reduce flow fluctuations, and by *land-use changes*, implying manipulations of the land-soil-vegetation system leading to alterations in the runoff-production process. A number of *water-related disturbances*, some of them natural and others man-made, complicate man's use of the water resources.

All water resources development is capable of having some adverse environmental effect. This is due to the close interaction between the natural water circulation through soil, subsoil and rivers on one hand, and the ecosystem on the other; water constituting a major transporting agent in distributing nutrients and disposal of waste products within the ecosystems. Ecological modifications are thus to be seen as inevitable consequences of human interference with water circulation in nature. In fact, the question is not *whether* there will be any environmental impact from a water project, but rather *how much* of that impact is at all acceptable (Biswas 1978). In other words, the benefits of a water scheme have to be purchased at the expenditure of certain natural assets due to different kinds of disturbances attributable to secondary effects of the modifications. These environmental impacts or water-related activities primarily affect the population living in the same river basin.

The transient nature of water also implies that the upper parts of a river interact with lower parts, so that man's upstream activities affect the potential activities further downstream. In other words, the hydrological interactions between the different parts of the system implies an interdependence between all water-related interests in the basin. Therefore, all people living in the same river basin are to a certain extent mutually interdependent as their living depends on and interacts with the same water resource. This simple fact creates huge development problems as 40 per cent of the present world population live in river basins comprising more than one country.

One important conclusion of the fact that a close interaction exists between man's land-based activities, water resources and ecological changes is that one has to develop an integrated view on land and water in long-term planning.

(3) Different Phases of River Basin Development

(a) Successive transformation from natural to fully controlled situations

With modernization, water demands rapidly expand. As population centres grow in size, and industries are established, point demands increase heavily. As agriculture develops, greater and greater areas need to be irrigated. Measures are therefore taken to adapt water availability in time and space to the corresponding demand patterns. In other words, water management advances, and water conservation makes possible increasing efficiency in the use of water in the river basin. From an initially natural stage, the river basin successively develops as time proceeds and water availability gets more and more controlled. In the end, a more or less fully controlled situation is achieved when the water resources of the river basin are used in an optimal way.

(b) Measures to increase availability and reduce water problems

In many developing countries, population density is very high. Local water conditions are, however, often insufficient for satisfying the increasing water demands. This creates problems. When two simultaneous demands cannot be satisfied, competition is created, and competing demands may develop into conflicts, either between individuals, between sectors of society or between countries sharing the same river basin. Often, a new generation of problems is created by the inadvertent effects of measures taken to simplify the water use or counteract problems. Secondary conflicts are created when measures taken to satisfy one water use are not compatible with another water use.

Evidently, different modes of increasing water dependability have high priority in stimulating social and economic development in these areas. The naturally available water can be augmented by different anthropogenic control measures. The soil moisture storage can be augmented by soil conservation measures, or by irrigation. The groundwater availability can be increased by augmenting the infiltration and percolation (for instance by reforestation) or by artificial groundwater recharge. The dependable river flow can be increased by augmenting the recharge of groundwater aquifers drained by the river, by importing water from a neighbouring river basin, or by storing flood water in surface or subsurface reservoirs. Other measures with the aim of augmenting local water availability are artificial production of water through desalination or rain-making activities.

The conventional way of arranging water storage in surface reservoirs involves great water losses due to evaporation. Therefore, subsurface storage is at present gaining in interest. In India, some attention is at present being paid to such possibilities. Storage space is established by pumping down the groundwater table during the dry season of the year or during a sequence of dry years. During the wet season or multiannual periods of water surplus, recharge is arranged by diverting flood water to the areas where natural infiltration to the aquifer takes place.

The most spectacular project of this kind is the "Ganges water machine" (Revelle and Lakshminarayana 1975). The background is that the Ganges plain has the potential to provide an agricultural production enough to feed 600 million people provided that it could be fully irrigated. This would make necessary an integrated

development of surface and groundwater resources by storing a portion of the monsoon flows underground. There are several ways of increasing the infiltration. In addition, evaporation losses from the water table might be reduced by lowering the groundwater table. In this way the water availability during the dry season might be increased by 75 km^3. This implies in fact a doubling of today's dry season flow (November-June) at the Bangladesh boundary.

Another large project with the objective of increasing water availability in water-scarce areas of India is the huge grid of water transfers by canals, river-stretches and pumping stations from the Ganges in the north to Cauvery in the south (National Water Grid). By means of this project a great number of river basins should be interconnected.

In the Coimbatore region of India, the water availability will not be able to satisfy the forthcoming demands forecast for the year 2000 (Sivanappan, undated). Several possibilities are at present being considered to avoid this devastating situation:

— desalination of sea water

— cloud seeding

— improved water-management techniques

— advanced methods of irrigation

— reuse of waste water

— importing water from northern- and west-flowing rivers.

Taking the time-dependent thumbscrew on available water resources into serious consideration, it is fully evident that futuristic studies have to be carried out on various realistic ways in which local water resources might be augmented, on how water conservation might be improved and on how water needs may be limited or even reduced.

(c) Three phase concept

A fruitful concept is to see the successive river basin development as composed of three subsequent stages: the natural (I), the gradually developing (II) and the fully developed (III). This concept is at present being further developed by Hungarian scientists (Dávid 1976, 1978). Its fruitfulness lies in the strong emphasis on the dynamic character of water management. It is based on the following philosophy (Fig. 2:11).

In period I, there is no significant water management activity in the basin. The water-availability configuration in time and space is able to meet the existing, already scattered demand pattern and water supply is arranged on a manual basis. Water management is therefore based on the individual making use of simple single-purpose low capacity structures. River water quality is natural or almost natural.

In period II, the real water-resources development starts, gradually expanding from a more restricted local character to an increasingly regional approach. Natural runoff conditions become increasingly altered and water availability gradually regulated. Structures and facilities established gradually turn multipurpose, forming ever larger and more complex water-management systems, with increasing capacities. Protection against water damage increases in importance, both from water surplus and from poor

water quality. Intrabasin water diversions gain in significance. With increased runoff regulations water dependability increases. Demand control is introduced as an alternative measure. Water quality deterioration due to discharge of waste water starts due to increased size and number of both point and diffuse sources. Environmental protection of the aquatic environment develops to counteract the negative impacts.

In period III, a complex and comprehensive management of the water resources is achieved. A fully controlled redistribution in time and space is developed, forming a dynamically balanced system of the whole basin, continuously operated to meet the demands. A comprehensive multipurpose water-management system extending over the entire basin is achieved. A coupling may be established between neighbouring basins by interbasin water transfer. In the end, all basins might be interconnected into an all-embracing water grid. The operation of this stage requires an advanced technology and an efficient and sophisticated infrastructure

In summarizing, one might say that water management in Stage I concentrates on *supplying* water, in stage II on *managing* water, and in stage III on *controlling* water.

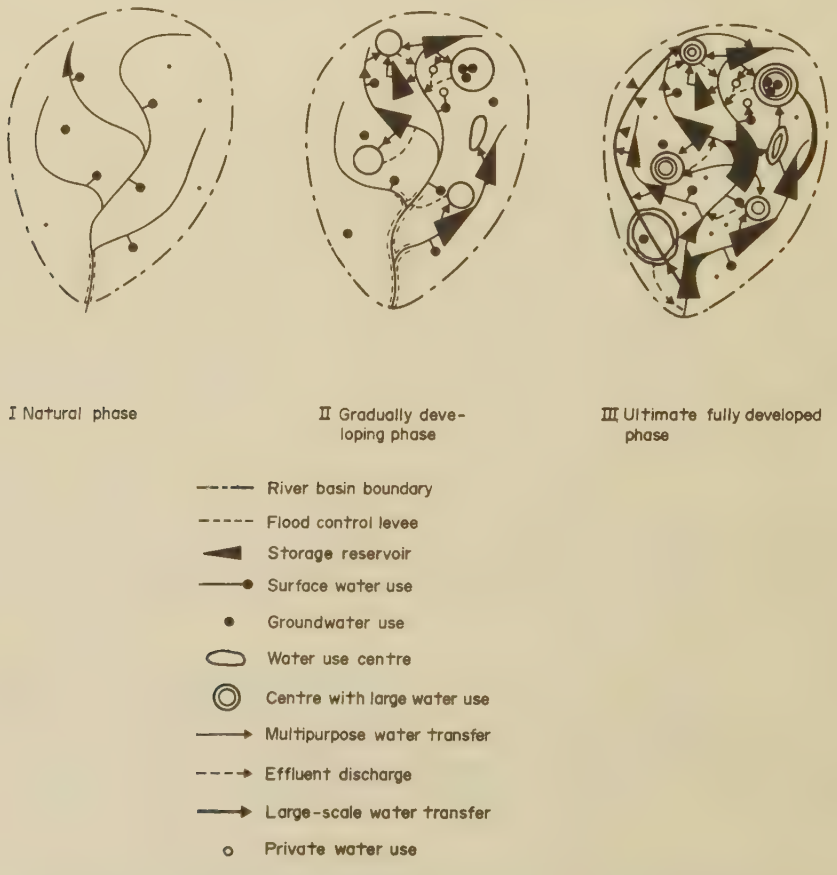


Fig. 2.11. A river basin in different stages of development. According to David 1978.

REGIONAL DIFFERENCES

(1) Availability in Relation to Withdrawal Needs

We have earlier discussed the absolute availability for water withdrawal represented by the total amount available. We are now going to look closer into this amount in relation to the needs for flow-related water uses. We might here introduce the concept *relative availability*, thereby denoting the amount available for each individual if equally distributed among the whole population.

The potential average water resources, determined by the hydrologic cycle, have been estimated by several scientists (Marcinek 1964, Nace 1968, Kalinin and Bykov 1969, Lvovitch 1973, Baumgartner and Reichel 1975). These estimates arrive at approximately 40,000 km^3 per year of renewable fresh-water resources. Leaving out the resources of the non-populated polar areas gives around 37,500 km^3 per year. If this amount is divided by today's population, we arrive at a relative water availability of 9,500 m^3 per person and year. For the year 2000, with the anticipated population increase the relative availability will decrease by almost 40 per cent to 6,000 m^3 per person and year. In interpreting this figure, one should consider that about 1,000 m^3 per person and year will be needed to attain and keep a decent standard of living (including requirements for agricultural and industrial use). Even if taking into account that this amount is an annual average of a factor that is subject to strong seasonality, there seems to be no risk of water deficiency on a global scale.

A study of the relative availability in different world regions, however, reveals that water scarcity will constitute a major problem in large areas of the developing part of the world. Figure 2:12 shows the potential amount annually available for each individual (by population 1973) in the twelve different main regions according to de Maré (1977). The importance of seasonality is indicated by the lines marking 20 per cent of the potential resources, which might—at least as a first approximation—be taken as an index of dependable water available during early phases of river-basin development. The dotted lines marking readily available resources (see further below) indicate what might ultimately be achieved towards a late stage of river-basin development.

Water scarcity does thus constitute a very real problem in large parts of the world, including North Africa and the Middle East, East and South Asia, and Southern and Western Europe, and to a certain extent also Eastern Europe and Central America. Water might very well be a critical resource for the general development in large parts of these regions, especially when taking into account that the amount available per individual decreases as the population increases further. This introduces a time-operated thumscrew on the available water.

We will return to this subject in a moment after having discussed the main hydrological differences between regions.

(2) Hydrological Dissimilarities between Regions

Even if the basic hydrological processes are similar in all physical environments, the size and relative importance of different water balance elements varies between regions.

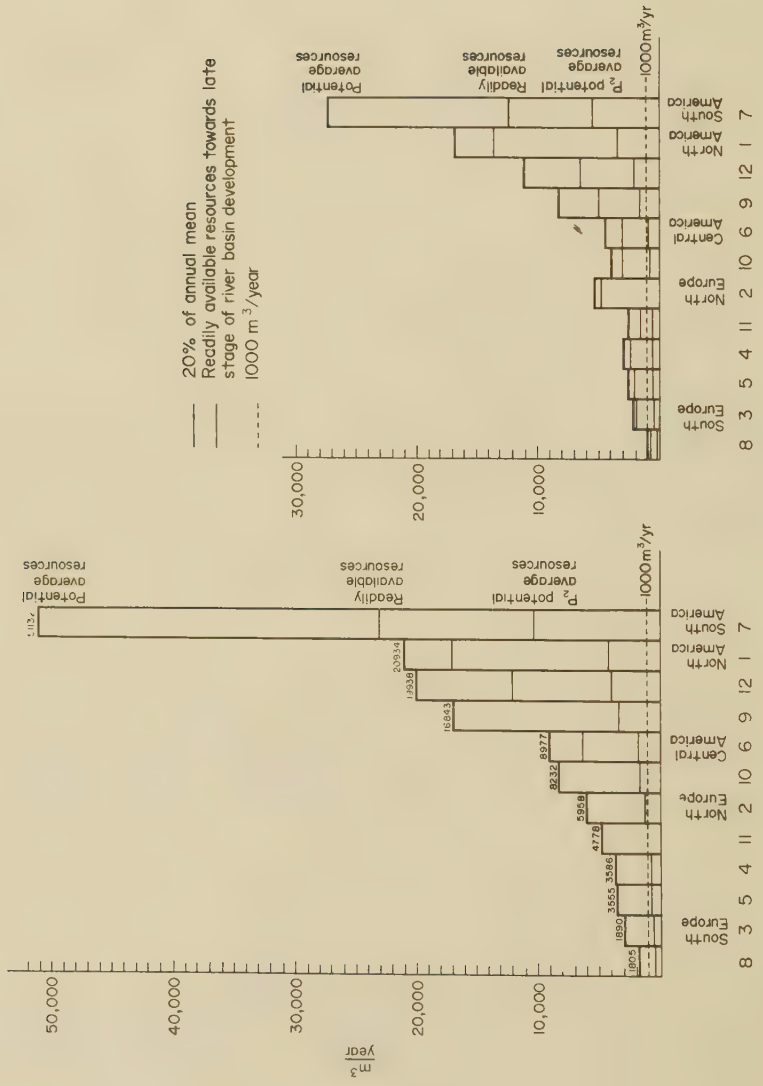


Fig. 2.12. Potential amount of annually available water on a per capita basis in the twelve world regions

a) Situation 1975.

b) Situation 2000.

(a) Regionalization approaches

There are several regionalization systems highlighting the main differences, classifying either factors influencing the hydrological regime of the physical environment or the flow regime as such.

Differences in hydrological response between different natural areas are basically caused by differences in general climatic and physiographic features. Response conditions can therefore be classified based on a generalized subdivision of the globe into natural zones, especially as the major natural zones to some degree also include a classification of vegetation and, although to a lesser extent, of soil types and weathering (Hadley 1975).

The IHP macroclassification of representative and experimental basins has the primary purpose of focusing factors of importance for the hydrological response of a river basin to different land use or land-treatment practices (Hadley 1975). The starting point in this regionalization is the climatic and physiographic characteristics of different natural zones. The first step is the combination of these characteristics by using simply the fifteen main natural zones (Fig. 2:13). Further steps may then be taken by adding in code-form a number of relevant characteristics of the precipitation pattern and of the geologic characteristics that might influence the relative amount of base flow.

The second type of regionalization systems is directed towards the runoff regime resulting from the response conditions just discussed. In this group there are three quite well-known systems.

The most classical system of regime classification is Pardé's system (Keller 1961). This system is based on the main source of the runoff, i.e. whether it is mainly fed by rain, by melting snow or by melting glaciers. The regimes may be simple, when there is only one feeding source and one set of extremes in the year, complex of first order when there are two feeding sources and two sets of extremes, and complex of second order when different feeding sources are active in the upper and lower parts of the river basin.

Chorley's system represents a combined type (Chorley 1969). It includes on one hand two climatic indices: a notation of the main climatic zone according to Köppen's classical climatic system including a temperature classification. On the other hand, it includes a classification of the runoff regime, thereby distinguishing between six classes based on the type of seasonality and its severity (appreciable runoff all the year (F), appreciable low-water season (M), marked winter low-water (W), marked summer low-water (S), nival and glacial mountain regimes (N, G)).

The third system in this group is the regime classification recommended for use within the IHP (Hadley 1975) and introduced by Lvovich (1974). (Cf. Fig. 2:13). This system includes on one hand, the basic source feeding the runoff (snow (S), rain (R), glacial meltwater (G), or groundwater outflow (U)) with different connotations to denote the relative degree of feeding from a certain source; and on the other hand, the season when main runoff takes place (spring (P), summer (E), autumn (A), winter (H)), with different connotations according to the relative amount of runoff during that particular season.

These regionalization systems can evidently be used as a first screening device when looking for basic differences between regions, for instance, between conditions typical for the zone where Scandinavian experts have been trained, as compared to the zone to which they are supposed to transfer their experience and assist in developing adequate water-related technology.

Fig. 2.13. Regionalization of the world, based on climate and geography. Numbers denote zone code, letters regime code according to Lvovich. From Hadley 1975.

If we concentrate our interest on Scandinavia, East Africa and the Indian subcontinent we find from Pardé's regime zoning that the predominating regimes are all simple: nival and fluvial oceanic regimes in Scandinavia, tropic fluvial regime in the subtropical areas. The main differences lie in the seasonal rhythms, determined by spring melting and autumn rains in the north, and by the rhythms of the monsoon rains in the two southern regions. The quotient of the flow extremes is normally much more extreme in the latter regions.

From the Chorley regionalization of runoff seasonality, we note that both East Africa and most of the Indian subcontinent have W-regimes, i.e. marked winter low-water. From the IHP physiographical regionalization we note that the two southern regions belong to the savanna zones: to zone 11 in case of East Africa, implying a short wet season, and to zone 10 in the case of India, implying a long wet season. The river-regime connotations of the IHP system mark summer maximums in India but autumn maximums in East Africa.

(b) Analytical approaches

Some scholars have approached the differences between zones in a more analytical manner. A classical approach is that of Wundt (1953), who described the annual evaporation and runoff as functions of the annual precipitation with different interdependencies for different annual mean temperatures (Fig. 2:14a). For tropical conditions he delineated some guiding curves showing the limits between which runoff would fall. In later studies, based on extended field data, Balek (1977) provided more general graphs for five different categories of catchments, classified according to slope of the basin, vegetational cover, and hydroecological classification. It should be pointed out though, that for most streams different stretches follow different graphs encountered along the course of the stream.

Today, the delayed runoff has gained in interest and has been further analysed for each of seven main hydroecological zones, based on analysis of a great volume of hydrological data collected in different parts of the world (Lvovich 1974). The interdependencies are based on the moisturization concept (W) (i.e. infiltration), describing evaporation (E) and delayed runoff formation (U) (determined as the base flow component from hydrographs) as functions of this factor.

The generalized graphs are shown in Fig. 2:14b. Each interrelation between (E) or (U) and (W) is composed of three different moisturization intervals, separating main intrazonal differences:

(a) Conditions of low moisturization ($W<W_o$) expressing a linear relationship between evaporation (E) as well as base flow formation (U) and moisturization (W). Practically all infiltrated water is used for evaporation and only a very small part percolates. In this interval, neither of those elements depends on the previous moisture retention in the soil.

(b) Above the moisturization level (W_o) the interdependence turns parabolic, expressing the dependence of both (U) and (E) on the previous moisture content in the soil. The larger the infiltration, the larger is the percolating part of it.

(c) Above a second moisturization value (W_1) the evapotranspiration has reached the potential level. Further surplus of water is used directly for recharging the groundwater.

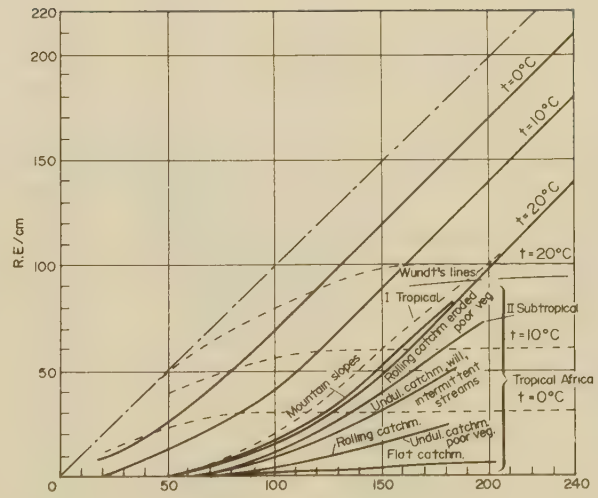
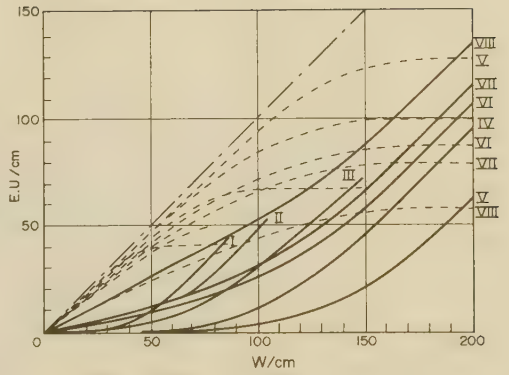


Fig. 2.14. Principal relationships between main hydrological elements (annual averages) in different zones

a) Relationships for different mean temperatures according to Wundt and for different topographical conditions in Africa according to Balek

P= precipitation
R= runoff (continuous line)
E= evaporation (dashed line)
1= flat catchments with deciduous forest
2= undulating woodlands
flat catchments with poor vegetation
3= rolling catchments with dense vegetation
undulating catchments with poor vegetation
4= undulating catchments with intermittent streams
5= mountain slopes
rolling catchments with poor vegetation



Index	Belt	Zone
I	Subarctic	Tundra
II	Temperate	Taiga
III	Temperate	Mixed forest
IV	Temperate	(a) wooded steppe, prairie (b) oceanic broad leaved humid forest
V	Subtropic and tropic	(a) steppe, desert savanna (b) dry savanna (c) humid savanna
VI	Subtropic and tropic	Oceanic monsoon forest
VII	Equatorial	Tropical rain forest
VIII	Mountain	Mountain oceanic monsoon humid forest

b) Relationships for different zones according to Lvovich

W = moisturization
U = groundwater runoff (continuous line)
E = evaporation (dashed line)

In regions with great altitude differences, the conditions are less clear-cut than in areas with less relief. Usually the soils in forest belts in hilly areas are characterized by a large infiltration capacity so that the groundwater recharge may even exceed the evapotranspiration. The precipitation is also higher and the temperature lower than in the plain, thus leaving more water left for percolation.

(c) Some key hydrological settings

Although there evidently exists within each zone a wide interval of intrazonal variance, some central values for the different water-balance elements might be used to typify the different zones. Table 2:2 presents type values for these elements for some settings typical for the areas of main interest in this report. Evidently the values have to be used with great caution: the intention here is only to highlight some main dissimilarities between the different natural zones, to which belong Scandinavia on one hand, and East Africa and large parts of India on the other (Fig. 2:15).

TABLE 2:2

TYPE VALUES FOR HYDROLOGICAL ELEMENTS IN DIFFERENT ZONES ACCORDING TO LVOVICH (1974)
(Unit mm/yr)

	Taiga	Dry savanna	Savanna of desert type
Precipitation	700	1,000	300
River runoff			
— flood part	160	100	18
— base flow part	140	30	2
— total	300	130	20
Moisturization	540	900	282
Evaporation	400	870	280
Potential evaporation	500	1,300	1,300
Base flow formation as a quotient of moisturization	0.26	0.03	0.007

In comparing these main settings, the following features are worth particular attention:

— the often much lower runoff production in the subtropical settings;

— the very high water deficit in these areas in relation to the vegetational water needs;

— the often very low groundwater formation in the subtropical environment;

— the considerable seasonality of surface-water availability in that area.

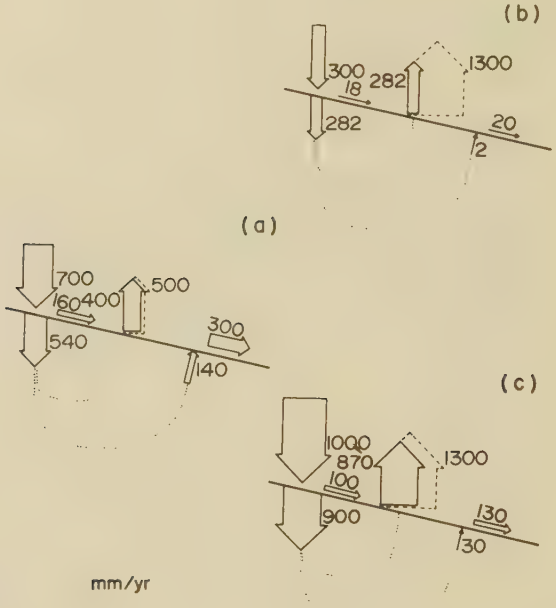


Fig. 2.15. Comparison between water balance elements in different zones. Type values according to Lvovich (1974). Arrow connotations of Fig. 2.1b.

5a: taiga zone (II)
5b: desert savanna (Va)
5c: dry savanna (Vb)

(3) Some Further Characteristics of Individual Regions

We closed the discussion on differences in relative availability by stating that the population increase introduces a thumbscrew on the available water. Let us now look at this problem a bit more closely.

It is evident that we cannot possibly hope to be able to utilize fully the water resources denoted as *potential resources*. Climatic and topographic conditions make it economically and technologically difficult or even impossible to overcome uneven regional distribution by diverting runoff from areas with a surplus to areas where the water is needed. In South America, for example, the Amazon accounts for about 60 per cent of the total resources of the continent. The enormous discharge of this river, added to the fact that there are large technological difficulties in storing the relatively large amounts of water flowing down the western slopes of the Andes justifies a low percentage of what can possibly be seen as *usable resources* (even in stage III of river-basin development ultimately usable). The same is true for the monsoon and typhoon regions of South and East Asia, where the climatic conditions make the situation severe apart from the difficulties in total utilization created by large rivers such as the Indus, Ganges, Brahmaputra, and the Mekong. In Northwestern Europe, on the other hand, the relatively small rivers with low variability in flow call for a much higher percentage of possible use (de Maré 1977).

Table 2:3 gives the ultimately usable resources for the different world regions. The corresponding relative availability amounts to 3,800 m^3 per person by 2000 as a global average, which implies a utilization of 25 per cent as a world average. When looking closer at the differences between regions both in relative availability and in prospective utilization ratios, three groups may be distinguished, each group having certain main types of water problems.

The first group consists only of Region 8—North Africa and the Middle East—with a prospective utilization ratio of almost 100 per cent. As this ratio is an average both over the year and over the geographical area the situation is extremely severe. The possibilities of supply augmentation by developing unconventional sources have to be considered, as in fact has already been done. In 1968, for example, 75 per cent of the world's total desalination capacity was installed in this region (UN 1973a). But equally important are, of course, sound water-conservation methods.

The second group consists of Regions 3 (Southern Europe), 4 (Eastern Europe), 5 (North and Central Asia), and 11 (South Asia). This area has a high population, giving prospective utilization ratios of 40-70 per cent. The area is generally semi-arid with large variations in rainfall and runoff. The main problem is therefore water conservation, both in order to save water for dry periods and to reduce the hazardous flood peaks during the wet periods.

The third group of Regions, 1 (North America), 2 (Northwestern Europe), 6 (Central America), 7 (South America), 9 (Central Africa), 10 (East Africa), and 12 (East Asia and Oceania), is more heterogeneous but with prospective utilization ratios below 25 per cent. Water is generally available throughout the year, so the main problems are those of developing existing resources without running into the difficulties of bad water-quality and related health hazards. This relates mainly to the developing regions, while the industrialized part has to be careful about industrial contamination of the water bodies.

(4) Some Subtropical Cases

Even within each group and each region there are large differences. Therefore, East Africa and India will be described in some detail below.

(a) East Africa

Although the relative availability for Region 10, here named East Africa, is comparatively high, this is not valid for all parts of the region. In the northern part (Kenya, Uganda, United Republic of Tanzania) the topography and geology make water not readily available from traditional sources, especially in the rural areas of the Kenyan and Tanzanian plains. It is not uncommon that the house is five kilometres or more from the water source, which might be a dug hole or well with small quantities of water (Tschannerl 1971).

In Kenya, there are essentially two large rivers, the Tana and the Athi/Galana which provide water for Nairobi and Mombasa and contain virtually all the hydroelectric potential of the country (Carruthers 1977). These rivers have a combined flow of about 6 km^3 per year, which is about half a percent of the flow of the Congo.

The total mean annual runoff of Kenya has been estimated to some 15 km^3 (ECA 1977). This should be compared to the population forecast for the year 2000 of 31 million and implies that the relative availability is of the order of 500 m^3 per person and year. Uganda is somewhat better off with some 33 km^3 per year and a relative availability of 1,300 m^3 per person and year. Uganda is also over all more fortunate than Kenya with locations of water sources (Tschannerl 1971).

TABLE 2:3

Region	Surface area (1,000 km^2)	Population (millions in year)			Potential average resources				Ultimately usable resources		Need year 2000		% need of read. avail. res.
					km^3 per year	m^3 per person and year			km^3 per year	m^3 per person and year in 2000	km^3 per year	m^3 per person and year	
		1975	1985	2000		1975	1985	2000					
1	21,515	236.6	262.4	296.3	4,953	20,934	18,876	16,716	3,962	13,573	1,013	3,420	26
2	2,568	233.8	245.1	262.1	1,392	5,953	5,679	5,311	1,253	4,780	195	745	16
3	2,105	173.0	194.3	229.1	500	2,890	2,573	2,182	425	1,855	177	773	42
4	6,316	291.7	321.1	357.7	1,046	3,586	3,258	2,924	837	2,340	565	1,580	68
5	28,761	1,072.3	1,238.0	1,448.7	3,812	3,555	3,079	2,631	3,050	2,105	1,302	899	43
6	2,733	105.6	142.2	216.9	948	8,977	6,667	4,371	664	3,059	103	475	16
7	17,820	214.7	283.2	402.7	10,978	51,132	38,764	27,261	4,940	12,267	191	475	4
8	21,114	235.5	314.4	469.0	425	1,805	1,352	906	340	725	331	705	97
9	7,448	134.0	177.1	275.4	2,257	16,843	12,744	8,195	1,354	4,917	175	635	13
10	7,150	111.4	149.8	235.6	917	8,232	6,121	3,892	734	3,114	150	635	20
11	4,986	792.3	1,038.2	1,434.1	3,786	4,778	3,647	2,640	2,272	1,584	1,197	835	53
12	12,573	336.5	448.0	623.0	6,709	19,938	14,975	10,769	4,025	6,461	549	881	14
World	135,159	3,937.4	4,813.8	6,250.6	37,723	9,580	7,836	6,035	23,856	3,817	5,948	950	25

It is to be noted that the mean annual runoff does not give a correct picture in this region with very large seasonality and fairly large variability. Thus, Botswana, for example, has about 500 mm annual precipitation, all of which falls during the summer. The annual runoff is estimated to some 1.2 million m^3 giving a relative availability of around 1,000 m^3 person and year in 2000. On the other hand, the variability is such that dry periods of two to five years are quite common.

The conditions in northern Tanzania are much the same. There is a five-month completely dry season from May/June to September/October and a rainy season with average precipitation of 700 to 800 mm. In Shinyanga Region there are about 1 million rural people living in 425 registered villages, few of which have a reliable water supply. In fact it was reported that about 800,000 people suffered from the lack of reliable water supply (de Ridder 1977).

Moreover, the provision of rural water supply in Tanzania is a complex problem from a technical point of view. Many of the Tanzanian rivers and streams flow through flat land where dam construction is usually not possible. Surface water supply is thus very costly, if at all possible. The same applies to the groundwater supply. The geological basement of Tanzania is composed of hard rocks which often lie very near the surface. There is a great risk in these areas that wells whether deep or shallow will be dry.

Another problem in Tanzania is the quality of the water. The surface water is often contaminated because of the seasonal floodings of the flat lands. In some areas, especially in the northern-central part of Tanzania, the groundwater is very salty and has a high content of toxic elements, especially fluoride of which concentrations as high as 330 p.p.m. have been reported (Bugaisa 1971). This has some relevance to the water supply problems of Tanzania, as a normal value is around 1 p.p.m., 1.5 p.p.m. may give mottled enamel, and 2-5 p.p.m. of fluoride may give rise to skeleton diseases.

In spite of all difficulties in providing water supply to the population in East Africa, the potential for a demand that increases many times over is obvious: see Table 2:4. It is clearly indicated that, for example, Kenya and Tanzania have a long way to go to arrive at the targets set for the next decades.

TABLE 2:4
COMMUNITY WATER SUPPLY AND IRRIGATION
IN SELECTED COUNTRIES

Country	Community water supply				Irrigation	
	Total population (1000)	(% served)	Rural population (% served)	Urban population (% served)	Irrigable area (1000 hect.)	Irrigated area (1000 hect.)
Botswana	631	29	25	100	35	2
Burundi	3,750	2	-	77		
Kenya	12,000	12	2	97	200	12
Malawi					112	10
Leshoto	900	3	-	100		
Uganda	8,864	25	20	89	93	3
Tanzania	13,077	13	10	54	536	40
Zambia	4,324	37	19	97		
Africa	285,000	33	19	73		
Developing world	1,726,000	29	14	68		

(b) India

There are four distinguishing characteristics of Indian water-supply conditions which determine the uneven distribution, both in space and time, of the Indian water resources. The first is the tropical climate, the second the monsoons, the third the high mountain ranges in the north and west, and the fourth is the peninsular shape of the subcontinent (Chaturvedi 1976). The rainfall is primarily dependent on the monsoons, which bring large amounts of moisture over the land mass. However, due to the tropical climate, only about 20 per cent of the moisture reaches the ground as rain or snow. Due to the topographic conditions large parts of India are situated in rain-shadow areas.

The south-west monsoon provides about 80-90 per cent of the total annual precipitation during the four summer months of June to September. One of the two monsoon branches originates in the Arabian Sea, meets the Western Ghats, where about 2,500 mm of rain falls, travels via the Indus plain and meets the Bay of Bengal branch at the Gangetic plain. Large amounts of rainfall are recorded here, ranging from some 4,000 mm/yr in the eastern parts to some 1,000 mm in the western part. On the other hand, there are large parts of the country that receive 600 mm/yr or less, notably the elongated peninsular area east of the Ghats and Rajasthan and Gujarat with areas (deserts) receiving less than 100 mm/yr.

Thus, large areas of India are faced with extensive droughts. According to Chaturvedi (1976), there is hardly any place in India not facing at least one month of water deficit (evapotranspiration exceeding precipitation). On the contrary there are large parts of the country which never have a water surplus in any month of the year. These parts coincide with the areas receiving less than 750 mm annual precipitation and with the areas identified as drought-affected by the Ministry of Agriculture and the Irrigation Commission (Rao 1975). These drought-affected areas, subject to inadequate and highly variable rainfall, contain 56 million hectares of cultivated area out of the country total of 160 million hectares and about 100 million people.

The total annual runoff in India has been estimated to 1,780 km^3 of which about 50 per cent is in the Ganges and the Brahmaputra. The annual dependable flow, i.e. the total surface and groundwater flows which are considered to be utilizable, amounts to 975 km^3 (ESCAP 1976). The total amounts of water withdrawn for different purposes as estimated for 1973-74 and 2000 are given in Table 2:5. The total demand for withdrawal water will exceed the dependable flow already around 1990. But some areas are worse off than others: see Table 2:6.

Although the figures given are tentative, they still indicate serious future water problems. The utilizable resources will be exhausted in several river basins, the pollution problem will be serious, and the environmental depravation will be universal well before the turn of the century. "Such a situation is bound to emerge unless we plan boldly and immediately" (Chaturvedi 1976).

(5) Climate Bias as a Development Problem

In the preceding sections, we have demonstrated that both hydrological settings and water problems are very different in different areas. This simple fact probably creates far more problems than are actually understood in the process of transfer of knowledge and technology.

TABLE 2:5

ESTIMATED WATER USE AND PROJECTED REQUIREMENTS, km^3/yr, IN INDIA 1973/74 AND 2000

	1973/74 (km^3/yr)	(%)	2000 (km^3/yr)	(%)
Rural domestic	6.7	1.4	16.4	1.1
Urban domestic	5.7	1.2	14.6	1.0
Industrial	4.5	0.9	55.4	3.7
Steam electric power	12.6	2.6	86.8	5.8
Irrigation	452.2	92.9	1,314.0	87.9
Livestock	4.8	1.0	7.0	0.5
Total	487	100.0	1,494	100.0
% of ultimate utilizable	50%		150%	

TABLE 2:6

APPROXIMATE YEAR WHEN WATER DEMAND WILL EXCEED ULTIMATE UTILISABLE RESOURCES, STATEWISE

State	1975 1980	1980 1985	1985 1990	1990 1995	1995 2000
Punjab				x	
Haryana			x		
Rajasthan			x		
Gujarat		x			
Uttar Pradesh		x			
Madhya Pradesh			x		
Bihar					x
Arunachal			x		
West Bengal		x			
Orissa				x	
Andhra Pradesh					x
Tamil Nadu	x				
Kerala			x		
Kamataka			x		
Maharashtra		x			

Not only is the knowledge to a large extent developed through research carried out in the temperate zone, but the water-related technology developed is adapted to geological and hydrological conditions prevailing in that zone. This means that the individuals on the emitter side in the transfer process, i.e. engineers and experts involved in technical assistance, administrative personnel in the aid organizations etc., are heavily biased towards temperate conditions. But also the individuals on the receiver side in the process, i.e. the universities and ministries in the developing countries, are often biased by irrelevant education brought home from universities in industrialized countries. This makes them, too, biased towards conditions and solutions adapted to temperate conditions. The difference in conditions is well illustrated by the global map in Fig. 2:3, showing

that the water-surplus conditions in the temperate zone are substituted by water-deficit conditions in the subtropics.

Many examples could be ennumerated on the effects of such climatic bias. One interesting example is the concept of effective precipitation. In India, as an example of a water-scarce area, this concept stands for that part of the precipitation taken up by the vegetation and effectively used for plant production. In Sweden, as an example of an area with a water surplus, the opposite meaning is given to the concept. It stands for that part of precipitation forming runoff, i.e. *not* taken up by vegetation.

A very costly mistake of climatic bias is the transfer to water-scarce areas of the western technology of water-borne sewage. Another mistake is the practice of leaving canals for conducting irrigation water unlined.

To this type of bias should, of course, be added also a cultural bias, which makes technical and administrative solutions feasible in the industrialized countries quite irrelevant in the cultural conditions in a developing country. In fact, the extent and effects of climatic bias is probably a research area very well worth looking into more closely. Studies should be made on different effects of bias in habits and understanding. Also the role of aid organizations in the transfer of non-feasible technology and management should be evaluated.

To a certain extent, the climatic bias in education is enforced by the fact that most textbooks focus on hydrological conditions in Europe or the U.S.A. Often, even a short review of global hydrology or dissimilarities between regions is missing. In other cases, the regional generalization presented in courses of water engineering or hydrology, is reduced to a discussion of global distribution of runoff regimes, of the index of dryness or of the interdependence between runoff, precipitation and evaporation for different air temperatures. Regional hydrological textbooks are mostly more descriptive than analytic in character. At present, there exists in fact no well-known textbook on regional hydrology with an analytical approach (UNESCO 1970, 1974). The production of such a technical aid in transfer of knowledge is badly needed.

SOIL AND VEGETATION AS HYDROLOGICAL KEY FACTORS

(1) Introduction

As stated earlier, soil cover and vegetation can be seen as key factors in hydrological phenomena and processes. "It is obvious that climate plays the basic role in the formation of the hydrologic regime. But no hydrologic phenomenon can take place independently of the soil and the plant covers. Soils and plants represent a kind of intermediary between climate and hydrologic phenomena and as factors of formation of the hydrologic regime, they therefore deserve special attention in present-day hydrologic science. ... The soil cover is the medium for complex hydrologic processes. Its infiltration capacity is a key factor in the formation of surface runoff. Water in the soil feeds both evapotranspiration and groundwater recharge. Soil moisture is one of the principal components of plant nutrition, and consequently is of great economic importance. The soil element in the hydrologic cycle can be effectively regulated by cropping practices and appropriate forest and water management" (Lvovich 1962).

The generalized runoff-rainfall graphs (Fig. 2:14a) clearly demonstrate the importance of both vegetational cover and degree of exposure to erosion. Thus, in catchments with a rolling topography, out of an annual rainfall of 1,000 mm about 150 mm forms runoff, if the vegetational cover is poor and the erosional processes pronounced. The runoff is reduced by almost a factor of 4, if the vegetation is dense, so that large water quantities are used up by the vegetation (Balek 1977).

Not only the total annual runoff, but also its time distribution changes with shifts in soil characteristics and vegetational coverage (Fig. 2:6). When the soil is hard and impermeable, most water leaves the catchment as flood flow charged with great amounts of silt from soil erosion. When the soil permits much water to infiltrate, as is the case in forests, more groundwater is formed and the base flow increases.

This high dependence on vegetational cover and soil leads to the conclusion that hydrological conditions in the tropics are quite susceptible to man-made changes within agriculture and forestry. On the one hand, degradation of the vegetational cover leads to increased and more rapid flood flows. The conclusion of this fact is that soil conservation, afforestation and other measures apt to increase infiltration are important to assure water conservation and more efficient use of water and to reduce losses of great amounts of water in rapid flood flows.

(2) Soil Water Regime and Plant Production

The soil cover constitutes one of the very basic natural resources of a country. It presents the basis for crop production, for construction of houses, industries and roads, it functions as recipient of wastes from human activity and it has the capacity to "clean" infiltrating water by decomposing many organic and organo-mineral compounds (Kovda 1979). Soil being the base for food production, man early detected that a poor production capacity could be improved. The actual soil is a product of very complex and slow development under interaction between factors of climate, minerals, hydrology, and biology. Measures of anthropological soil amelioration imply an improved soil water regime, reached by a complex of measures including irrigation, soil management, and fertilizers. By such measures a several-fold increase can be reached in soil productivity, a fact of immense relevance in regions with average yields below 1 ton per hectare, a present food deficit, and increasing shadow populations. With wise application of a complex of different measures and a profound understanding of the processes involved in the actions of the soil system and the ecosystem, even a long-term improvement of productivity conditions might be attained.

History has, however, witnessed more examples of long-term failures than of long-term successes of intended soil amelioration. An important aspect of this depressing fact is again a climatic bias in the transfer of technology from regions with different soils and different climatic conditions. Already in 1952, Hyams in his excellent book on soil and civilization (Hyams, 2nd ed. 1976), outlined the general pattern of interaction between man and soils in different world regions and seen in a long-term time perspective. He makes a distinction between different possible roles of man: man as a parasite on soil, man as a disease of soils, and man as a soil-maker. One of the important conclusions presented is that the soils of Atlantic Europe at present constitute the perfect artificial soil in spite of perturbation when an alien and climatically biased technology was forced on the region by the invading Romans. A factor working in the opposite direction was later the large-scale emigration during the eighteenth and nineteenth centuries to North America. Other success stories included the soils of the Western Andes during the Inca empire.

The history of mankind has, however, witnessed more examples of soil deterioration than of soil improvement. It is almost impossible to restore destroyed soils artificially, as the conditions of their formation cannot be reproduced. Therefore, the creation of new soils constitutes a better solution and an adequate goal in regions with low fertility soils in order to improve the conditions of food production as a base for further economic development. In the general process of soil amelioration, as well as soil deterioration, water constitutes one of the key elements.

(3) Salinization and Waterlogging

Main hazards when improving the soil water regime by means of irrigation are salinization and waterlogging. It is a matter of paramount importance to avoid a long-term accumulation of salts in the soil. Even if the possibility of salinization has to be taken into account in almost all soil-climatic zones, it is of especial importance in the tropics, as the natural conditions in that zone make most soils prone to secondary salinization. Therefore, any salts emerging from the groundwater or from the irrigation water and accumulating in the soil have to be leached away by applying a surplus of irrigation water. In addition to this, the leaching water has to be evacuated from the area by adequate drainage, as the soils, in their natural conditions, are not very well drained; artificial drainage has to be arranged by introducing a deep horizontal drainage system.

Kovda (1979) has presented an excellent summary of the secondary salinization problem and the measures necessary to avoid it, and the reader is referred to this for further details and references. There exists a close relation between salt content of the soil and its physical properties, the presence of soil agregates, and humus, and therefore the soil's capacity to store water in the root horizon.

Today, salinization constitutes a large-scale problem of global dimensions: the total area of barren saline lands once fertile has been estimated to be about 20 million hectares. In the U.S.S.R. great research effort has been put into reclamation of deteriorated soils and the results indicate that a combination of leaching and deep horizontal drainage can be quite successful in reversing the process. There are different types of salinization depending on the geochemical characteristics of the actual region. A distinction may be made between soils dominated by soda, sulphate, or a combination of chloride and sulphate.

A key to the salinization problem is presented by the salt-water balance equation. It states that the input of salts with the irrigation water has to be balanced by a corresponding output of salts with the groundwater, naturally drained from the area, and the water artificially drained from the area. At the same time, there has to be a balance also as regards water as such, in order to maintain adequate groundwater conditions. If there is a surplus of water accumulating on a long-term basis, the groundwater will rise and waterlogged conditions will develop. If the opposite conditions prevail, the soils will get dryer. In order to be able to apply the condition of balance in the planning and development of irrigation systems, the planner has to have access to basic information on the relevant conditions. As a consequence, statistically reliable data have to be gathered on the salt content of the irrigation water and the natural groundwater already at the planning stage. The amount of drainage necessary should then be computed from the balance equation.

(4) Fertilizers

Another most important role played by the water present in the soil is the transmittance to plants of fertilizing substances necessary for their growth. In soils with poor fertility the application of fertilizers forms an important part of farming. The artificial fertilizers used at present have, however, to be improved in order to avoid the situation where unused fertilizers cause environmental problems when washed away into the groundwater and to the rivers. High nitrate content in groundwater, for example, introduces health hazards, when groundwater is used as drinking water. Fertilizers in the surface water cause eutrophication. As also suggested by M. Biswas (1979), new types of chemical fertilizers should therefore be developed with the ability to remain in insoluble form in the soil when not needed by the plants, but to release their content of substances in dissolved form into the soil solution during the growing season at a rate corresponding to the need of the growing crop.

(5) Water Forms a Crucial Element in the Landscape

Water plays two opposite roles from the point of view of the landscape. Moist soil as well as a protecting plant cover are important ingredients in the landscape in protecting the soil from erosion during the intense rains typical for tropical conditions. At the same time, water is a main agent in causing erosion of unprotected soil surfaces. Under conditions of expanding desertification following from unwise land-use, the risk of water carrying away productive soils constitutes a major hazard to food production in over-populated tropical lands. According to a recent estimate by FAO, 22 per cent of the present degradation of the earth's surface could be directly related to erosion (Biswas, M. 1979).

The countermeasures necessary to avoid soil deterioration by erosion by reducing the erosion risk on undulating arable lands are well known and widely applied in the tropics. They include terracing and reforestation. In some areas, e.g. Kenya, the organizing of work during colonial time created a deep aversion to such measures. The main obstacles to the application of the existing knowledge may, therefore, sometimes be more socio-political than technical.

(6) Water, Ecology and Environmental Impact

As already stated earlier in this book, environmental impact follows most manipulations in nature in which water is involved. The vast occurrence of adverse environmental effects of natural resource development experienced by industrialized countries contrasts at present with tendencies in developing countries to give higher priority to short-term development goals than to long-term maintenance of the resource base in terms of groundwater availability, soil deterioration, etc.

As pointed out by Tolba (1979), the development goals are different in industrialized and developing countries, and the environmental impact problem leads to different conclusions in the two cases: "In the developing world, which still lacks the infrastructure and readily usable resources required to meet the growing needs and aspirations of its peoples, the new kind of development must continue to have a strong physical orientation". In the industrialized countries, on the other hand, the present situation is quite different. There, "it will be necessary to reorient society's aims so that the entire population will have more opportunity for self-expression in the fields of culture, education, the arts and humanities".

A good starting point for any discussion on natural resource development seems to be that adverse environmental effects are difficult to avoid. Even if environmental effects are unavoidable and should be seen as the price that has to be paid for achieving the desired result from the project in question, they can—and should—be controlled. The natural place to start the control is at the planning desk. A check list might be quite valuable at this stage, so that the planner may feel sure that all relevant aspects are taken into account.

Experience of the sensitivity of the environment to man-made changes would seem to be an important part of the knowledge transferred from industrialized to developing countries. There is, however, in these countries a certain tendency at present to reduce the importance of environmental impacts, and discussions in international groups are not always as constructive as one would desire and as the importance of experience would demand.

The fact that goals and approaches are so different contributes strongly to difficulties in the exchange of information between industrialized and developing countries. There are a number of cases where differences in general approach occur between different sectors of the environmental concept. To facilitate this process it would be helpful to break down the concept of environmental impact into its subparts. Asit Biswas (1978) bases such an exercise on the subsystems involved and

discusses the impacts in terms of the physical, chemical and biological subsystems. When the general goals of economic development are different in different parts of the world, the priority given to different aspects of environmental quality would suggest basing a subdivision on different aspects of environmental quality, as illustrated in Table 2:7.

TABLE 2:7

DIFFERENCES IN CONCEPTUAL RELEVANCE OF ASPECTS OF ENVIRONMENTAL QUALITY

Aspect	Relevance for developing country settings	Relevance for industrialized country settings
(1) Resource base		
soil productivity	x	x
groundwater availability	x	x
soil erosion	x	x
fish	x	x
(2) Health aspects		
water-related diseases	x	
unintended reuse of industrial waste water		x
(3) Preservation of habitats		
stream valley vegetation		x
wetlands		x
endangered species		x
(4) Cultural aspects		
archeological objects	x	x
water aesthetics		x

Keeping the environmental impact under control is impossible without a profound understanding of the processes. To a certain extent the necessary knowledge is already at hand, and a first level goal would therefore be to systematize this knowledge and make it available for all those who need it. In this process any climatic bias has to be avoided. One way of doing this is by introducing climatic conditions as a parameter. The importance of climate has recently been illustrated by Asit Biswas (1979a). In order to achieve such a structuralization, one has to penetrate the main processes—physical, chemical, as well as biological—involved in the different ecological interactions concerned. The application of the knowledge in a different climatic environment has always to be based on adequate acquaintance with the characteristics of local conditions. Here again, a data base is a necessary prerequisite for successful application in one environment of knowledge developed in another environment.

Basically, water plays a number of different roles in the way in which environmental impacts develop, i.e. in the sequence of processes involved from primary manipulation to experienced ecological effects. It seems that water plays at least five different roles:

(1) Role of physical dispersion of pollutants both in dissolved form and in suspended form: this may be achieved by the water flow as such, or by a combination of processes in the atmosphere and hydrosphere like the gradual spreading of

hydrocarbons to ecosystems by evaporation and subsequent precipitation (Biswas, M. 1979).

(2) By its action in transmitting water-related diseases: this can be achieved by the dispersion and transfer of infectious agents in the water phase (water-borne diseases) or by presenting a habitat for a host organism for this agent (water-based diseases), or a habitat for the transmitting organism itself (water-related diseases with insect vectors).

(3) This role has to do with the erosion-sedimentation sequence of processes and has far-reaching consequences both in the form of direct erosion effects causing loss of soils, of changed distribution patterns of fertile agents in suspension and of sedimentation in new standing waters constructed to store water, but in reality losing storage volumes continuously by sediments from the river basin above the reservoir accumulating in the water.

(4) The role played by the water solution in the soil for maintaining crop growth and the fertility of the soil: imbalances causing soil deterioration by salinization and waterlogging.

(5) The role of water in maintaining the vegetation cover and the physical conditions of the soil as a protection from being carried away by wind deflation or water erosion.

(7) Land Management, Soil Conservation and Water Development

We have seen that there is a close interplay between land-use and water availability, and between water and soil productivity. This creates a close link between land-use planning and the planning of water projects. Not only in order to increase the available amount of dependable flow in a river, but also as a measure of soil conservation, it is of great importance in many regions to reduce surface runoff by adequate control measures. Normally, this involves storage of the waters. It is an unwise investment to install large-scale water storage in reservoirs without a simultaneous development of land management and soil conservation in the river basin upstream of the reservoir. This has been experienced in the Tana river in Kenya, where the main part of the storage capacity of the Kindaruma reservoir vanished in 10 years, due to sedimentation of silt, eroded from upstream lands.

CHAPTER 3

Manageability and Unmanageability of Water

INTRODUCTION

This rather unwieldy (or unmanageable) title means that we will now look at some of the features of rural water supplies and irrigation from a management point of view. We will, thus, mainly deal with human and social problems in this section.

Of course, we cannot tackle everything, but we have chosen to look at rural water supplies and irrigation in terms of:

operation — including water allocation, general management problems and questions of efficiency, and a short section on flood control;

maintenance — some few management aspects of a rather technical topic;

education — education and information include not only the often called for education and training of farmers but also the changes needed in the training of engineers and technicians and so-called experts away from the climatic and cultural bias now existing;

size — including the size of problems as well as of projects.

This rather select collection of observations is to be regarded as an introductory survey of the gaps in our knowledge and the research suggestions we present in Chapter 7.

To many readers, the problems presented in this section will not be new: the specialist in irrigation will probably want to discuss several other problems, the specialist in rural water supplies may have a different view of what is important. A total coverage is not possible and to the authors it has seemed reasonable to bring forward here some problems or areas which seem important to them. We have also decided to sort the material not according to the common divisions in rural water supplies, irrigation etc., but rather into other categories, to see whether there are — and there are! — common features or problems within the field of, say, operation and maintenance or recurrent finance.

OPERATION

(1) Introduction

We have made a distinction between operation and maintenance for several reasons:

- Operation is taken to include questions of administration and management, efficiency in general; and in discussion of the operation of irrigation systems we have chosen to discuss water allocation as this includes both operational aspects and is a focus for interdisciplinary research (Bottrall 1978).

- Maintenance is the routine care of installations (embankments, pumps, structures) and the periodic rehabilitation of such installations. It has as its purpose to provide conditions in which good operation and water allocation is possible (Bottrall 1978a, Levine and Wickham 1977).

- The skills required for these activities are different. Operation involves dealing with systems, personnel, farmers, small and big land holders, planners etc., handling the allocation of water, whereas maintenance can be done without any contact with farmers or end-users.

Most administrations ask their irrigation and water-supplies personnel to undertake both functions. As Levine and Wickham say: "Maintenance activities almost always predominate in their day-to-day work ... because accomplishments in the field are more visible. The system of rating ditch tenders in the Philippines is based largely on the extent of grass cut along canal embankments at certain times of the year—a criterion which is at least easy to measure. The distribution of water from several hundred turnouts over a season could not be rated in that way" (Levine and Wickham 1977, cf. also Takase and Wickham 1976).

There is an increasing amount of literature on the problems of operation and allocation of water, less so on maintenance. We know, however, fairly little of the operating experience of irrigation of rural water supplies, as there are few analytical studies (Carruthers 1976). This is important, because there is (maybe because of the lack of such studies?) little feedback from operational problems into the planning process. This feedback loop is especially important as the planning and design of systems and the operation of systems tend to become separate specialities in the engineering profession.

(2) Rural Water Supplies and Sanitation

(a) Introduction

The interest in the provision of rural water supplies, or rather safe water supplies for rural areas, has lasted more than twenty years. In the beginning, interest in such installations was based on the rather simplistic idea that if people changed from impure water to a clean water supply, tremendous health benefits would automatically be the result. In consequence, a healthier population would also contribute more to the "economy" and therefore also to "development".

A further idea was the social benefits which would accrue: women spent too much time on the water-collecting journey each day and water supplies provided closer to the village or the house would alleviate the plight of women. Or they would make it easier to use her labour more effectively in the agricultural "economy".

Unfortunately, these ideas have turned out to be, at best, half-truths. The questions asked in earlier studies were those relating to daily water consumption, walking distances, project design and field construction and organisations for water-supply development. Seldom did we hear questions about development objectives: Who gets the water? Are the levels of supply adequate? What are the investment alternatives? What are the methods of evaluation? What is the impact of project implementation on the local community? To what degree has Rural Water Supply contributed to the fulfilment of national aspirations and objectives? Richard Feachem and Ian Carruthers have analysed some of the contributing factors in Volume 1 of this collection. Feachem explains why the link between water and improved health is tenuous indeed: it is a matter of making people use exclusively safe water supplies—and it is quite clear that this is not the case. People travel; we do not know what children drink; and as people do not tend to use more water for food and personal hygiene, unless the water tap is in the house or the courtyard, diseases which could be washed away with more water still prevail (Moore *et al.* 1966). Unless personal hygiene and appropriate sanitation facilities are improved, the mere provision of safe water is not enough.

Ian Carruthers (178) explains the problem of costs and benefits, both economic and social. In certain areas, the water-collection journey has been shortened, but that is the only social benefit experienced so far. The social and political history of water supplies shows social and economic problems of another dimension: the benefits accrue to the rich and influential and have increased the gaps between the already existing economic strata in the countryside (Kneese 1968). The whole area of the social impact of water supplies is little known. Some recent experiments with a social cost/benefit analysis of water supplies and quality of water supplies have at best rather inconclusive results (URT 1979). Benefits accure maybe not in health or saved time, but in the set of cumulative changes which these make possible (Saunders and Warford 1976). Two more problems must be mentioned.

The population of the rural areas of the world has been promised water within reasonable distance of its home and sanitation facilities before 1990. To attain the Water Conference targets by the year 1990 it has been estimated that the current level of annual investment has to be stepped up as shown below:

Rural Water Supplies	3.9 times the present annual investment
Rural Excreta Disposal	4.0 times the present annual investment

During the period 1971-75 investments totalling some U.S.$ 2,250 million were made for rural water supply and U.S.$ 450 million for rural sanitation. (At the same time, there were investments for urban systems of U.S.$ 9,000 million for water and 3,400 million for sewage disposal) (UNICEF 1979).

And it is obviously not possible to expect all that capital to come through the technical cooperation channels. Capital has to be generated locally and the technology has to be changed to some level appropriate to the means of capital formation (cf. URT 1977 for suggestions). However, of investments mentioned above, roughly three-quarters were made from internal sources, which is astonishing when considering the extreme shortage of capital for competing sectors. Developing countries *do* realize the importance of clean water and sanitation (UNICEF 1978). The whole question of pricing and financing of water schemes belongs here, as well as the many questions of the relations between consumer, their expected level of service and the producer. Systems involving choices by users themselves and an analysis of the risks they are willing to take and what they think the benefits look like may bring lasting benefits. (Bradley 1974, Burton, I. 1974, White 1974). This includes local participation in planning and decision, local organization and the understanding of such organizations.

Such arrangements may also help to solve the second major problem: for some years we have been aware that the rate of new constructions cannot keep up with the installations that fall into disuse for a variety of reasons. The main problem areas seem to be precisely lack of public participation and lack of funds for recurrent costs, operation and maintenance of installations.

An additional problem may be that the goals have been set over-ambitiously. The International Drinking Water and Sanitation Decade ("Water for all by 1990") has set some well-publicised but unrealistic targets. Some authors think that the national and international concern with such targets is the prime reason for the emphasis on construction and capital investment and the consequent neglect of operation and maintenance activities (Cairncross *et al.* 1980).

Many of these problems have been discussed in the works summarized in the excellent little 1974 volume from the IDRC, Ottawa (White and Seviour 1974).

We would now like to discuss in slightly more detail some of the questions raised. The rationale for investments in water were better health and less work for women. The magnitude of the task caused a trend towards heavy capital investment and towards the largest possible construction volume. (Swedish investments alone in this area— via SIDA—have been close to 1200 million SwKr or U.S.$ 300 million, mainly in Eastern Africa). Stress on construction and capital investment made central administration necessary in recipient countries, manned with expatriates, using foreign solutions and imported technology. This situation has caused problems mainly in four areas: design and construction, recurrent cost and financing of installations, administration and local participation. A fifth area of concern has been the whole and somewhat neglected question of sanitation.

(b) Design problems and capacity/consumption estimation

Although we have tried in this volume to stress political, social and economic problems, it is important to remember that technical problems also affect the desired standards of water supply services.

Among the technical problems, maintenance and operational problems are most important and will be discussed below. But, for example, among the schemes evaluated by the Government of Ethiopia in 1975, 53 per cent were poorly designed with ensuing poor capacity of distributing water (GOE 1976). This seems to be a rather common feature of earlier installations. The technology brought by foreign consultants was not up to standard or inappropriate (Frankel 1972). Donors and receiving countries were sold shoddy goods such as rusting pipes, substandard pumps and taps which fell apart. Many systems also have capacity problems and pressure problems.

Construction has not kept pace with schedule in some countries (ROK 1977) and construction overruns are up to 100 per cent. The reason for this is shortages of transport, materials and skilled manpower, and restrictions on recruitment. Overoptimistic planning is another reason. The critical points being uncertainties in demand parameters, unrealistic supply estimates and inadequacy of data in general. In 1970, records in Tanzania were inadequate to determine the number of people actually using water from improved supplies (Warner 1970). The situation is the same in 1979. The rates of water use, and the actual consumption measurements are lacking or wildly different.

TABLE 3:1

RATES OF WATER USE

Name of Investigator	Number of Sites	*Per Capita* Daily Consumption (Litres)	Remarks
Stanislawski	1	Daily range: 14.6-41.8 Average: 23.2	Probably underestimated
Crawford	1	Average: 59.1	Likely overestimated
White *et al.*	19	Site range: 4.4-20.8 Average: 11.4	Only includes water carried to the house
Warner, unpiped	21	Site range: 5.0-26.4 Average: 12.7	Only includes water carried to the house
Warner, piped	11	Site range: 9.1-22.7 Average: 14.1	Only includes water carried to the house
Ferster	6 (But measured in wet & dry season)	Daily range: 14.2-27.4 Average: 18.7	Only includes water carried to the house

Source: Warner 1969.

Official estimates of the population served by improved supplies may be optimistic. Accepted statistics may not be valid. It is mentioned for example that the 1972 WHO estimates reproduced in the Kenya 1972-78 Development Plan greatly overestimate the numbers of consumers (ROK 1977). Several observations from several countries seem to corroborate this problem. Most often men have been asked about water consumption because investigators, being men, have not had the opportunity to ask women who do the work. For men, the water supply is always adequate and this results in an underestimation of the needs for rural supplies.

Field research in Kenya has confirmed that on most schemes local residents (up to a third) prefer not to use the improved source. This again has to do with seasonality of demand and the fact that the installations are meant for dry-season water collection, whereas during the rainy season other water sources are closer at hand. Other examples (ROK 1977) show that the low demand and the reluctance to pay for water during the rainy season may be caused by the simple fact that people are unable to pay during the rainy season (Agnew 1975). For example, people in rural Ethiopia get most of their cash income during a limited period at harvest time in the dry season, but in the rainy season most crops and most cash have been consumed and there is starvation also in so-called normal years (GOE 1976).

There are estimates from Tanzania which show that 50 per cent of villages are overpopulated in relation to design capacities because of the unexpected move to villages recently provided with water supply. The situation is the same in Kenya. Jacobsen, Ascroft and Padfield (1971) report that the water supply tanks common

in Kenya are frequently or almost constantly without water. The most important reason seems to be that the capacity is so small that users close to the source use all the water, leaving no water for the far end of the system. This, again, has to do with the fact that the population relying on the water scheme has increased far above the design level. Proper functioning may also be hindered by excessive withdrawals close to the source (ROK 1977).

In the course of time, the demand for private connections grows and operators without knowledge of design principles install direct lines to consumers. It may also happen that people living just outside the supply scheme begin asking for connections. It can be expected that the most influential households will then be connected. These kinds of non-planned connections without metering and flow-restriction devices, are supposed to contribute extensively to a suboptimal performance as is illegal withdrawal for minor irrigation. Direct consequences are that Communal Water Points are closed and break pressure tanks are by-passed. This forces unconnected people back to old water sources.

Sometimes the root cause of low pressure in the distribution system is not the demand estimate but the supply estimate. Often the reliability of the source flow is very low, since the hydrological estimates have to be based on spot checks where there is no regular gauging. This is, of course, most valid for small sources, but also in general for shallow wells as reported by de Ridder (1977). In the Dutch program of 350 shallow wells in Tanzania, 20 per cent had reduced yield and 15 per cent showed no yield at all. De Ridder refers to four explanations for this malfunction:

(a) As very little is known about groundwater yields and groundwater fluctuations in areas for new villages, the wells were not made deep enough.

(b) The sites for the wells were not suitable, but wells were sunk anyway under the motto that a low yielding well is better than no well at all.

(c) The wells were operated above their maximum capacity. Wells designed for normal use, i.e. for pumping during a couple of hours in the morning and in the evening, are often pumped almost continuously.

(d) Faults in construction make well filters clog with silt or clay particles, which causes considerable reduction in well yield.

The Dutch programme in Tanzania has, however, recently developed some very interesting low-cost new technologies: improvement with concrete rings and slabs in shallow wells, and the boring by hand of shallow tube wells (15-20 m) with augers turned by four men.

For South-East Asia a recent study concludes:

Design Criteria

> "Most countries in South East Asia have been following design criteria established by expatriate agencies involved in their programmes at one stage or another, and leaning mostly towards European standards and usage. Bangladesh has been following a DPHE Handbook prepared by M/s Camp, Dresser and McKee who were the consultants to the Department for about a decade from 1964. Apart from the specifications provided by the consultant the department has itself drawn up specifications for rural water supplies. Burma is yet to establish design criteria other than those followed by the

consultants in preparing its urban schemes. India has prepared a detailed *National Manual on Water Supply* laying down the design criteria, design parameters and values for urban and rural water supplies, adapting from British and American practice. Similar criteria for sewerage projects are under publication, but the States have laid down their own criteria for guidance. In Indonesia, design criteria and standards are yet to be developed. In their absence, the designer is left to his own discretion. Standardisation among the member countries has been inhibited by the application of a variety of donor country standards. In Nepal, the urban designs are based on expatriate expertise employed with foreign aid; criteria for rural schemes have recently been recommended by a WHO consultant. In Sri Lanka, the National Water Supply and Drainage Board has recently laid down its design criteria. In Thailand, the Provincial Water Supply Division and the Rural Water Supply Division have adopted American/British practice to prepare the design criteria for urban and rural supply systems. Design criteria for sewer systems are yet to be evolved." (WHO 1977).

(c) Capital and recurrent costs

A main problem of operation and maintenance and administration is the different emphasis on the provision of capital for new installations vs. provision of capital for recurrent costs. A small donor country like Sweden has supported the development of water development in 14 countries with grants, loans and technical assistance. The total financial aid, which amounts to U.S.$ 250 million is distributed as shown below:

TABLE 3:2

SIDA'S BILATERAL SUPPORT TO THE WATER SECTOR DISTRIBUTED PER COUNTRY 1965-1978

Country	U.S.$ (million)	Country	U.S.$ (million)
Bangladesh	6.9	Somalia	2.3
Botswana	14.9	Sudan	11.4
Brazil	5.9	Tanzania	110.5
Ethiopia	5.5	Tunisia	34.8
India	2.3	Turkey	3.4
Kenya	43.9	Zambia	0.5
Lesotho	3.0	Special programme and research	2.7
Pakistan	2.0		

Source: Rosenhall and Hansen 1978.

In addition to the above bilateral support, SIDA is also contributing to the water sector through the UN organization and through regional development banks. Table 3:3 shows the bilateral support broken down into various categories within the water sector.

TABLE 3:3

SIDA'S BILATERAL SUPPORT TO THE WATER SECTOR DISTRIBUTED PER CATEGORY WITHIN THE WATER SECTOR

Category	U.S.$ (million)
Precipitation, evaporation, run-off, erosion	6.4
Water use (irrigation, forests, water supply)	134.7
Hydropower	47.6
Planning, operation, programming, costs	18.8
Effects (social, medical, ecological, environmental)	9.6
Water re-use	3.2
Research and education	29.7

Source: Rosenhall and Hansen 1978.

Although some funds for operation and maintenance are hidden somewhere in these figures it is quite clear that the donors produce capital costs and leave the operation and financing costs to the receiving country. It is rather easy to show that, with an increasing capital investment and an increasing number of installations, receiving countries do not have the funds nor the manpower to look after the installations. Development projects, for example in Kenya, thus consume large parts of the national budget for recurrent costs (Harlaut 1978). Ideally such money should come from revenue collected. Such collection is an administratively difficult question, and revenues do not materialize: poor organization of the water-fee collection, no registration of consumers, formal sanctions never used, informal sanctions not established (Storgaard *et al.* 1971). This Kenyan example shows a situation which at present is similar in many countries.

The present unsatisfactory state of many water supply schemes would have been even worse had it not been for some heroic assumptions on what constitutes development costs and what recurrent costs (Schultzberg 1978).

In South East Asia, according to WHO (1977), the institutional set up is generally oriented towards spending money allocated by the Government, without any responsibility for ensuring financial returns on the investments. Operation and maintenance (O and M) of rural water supply are invariably entrusted to the local-level authorities without any mechanism for proper monitoring of the services and without financial possibilities and responsibilities. Thus the costs of the operation and maintenance have to be met directly by the Government, which in itself is a major problem unless O and M services are regarded as important in development and construction and unless Governments put more emphasis than before on rural and small-scale projects instead of urban and large-scale projects (ESCAP 1976).

Even capital costs will in the future constitute a problem. The enormous amount of installations necessary to meet the targets set by the 1977 Mar del Plata conference will require enormous amounts of capital. Such capital has to be generated locally as well as funds for operating and rehabilitating the installations (URT 1977). A low cost technology is therefore also imperative (Taylor 1967).

(d) Administrative problems

The problems of design and funds, discussed above, influence administration and management in a decisive way. Unreliability, impairment caused by bad design or bad management affect the willingness to pay for water and thus the already limited capacity to generate funds for running costs and new constructions. Many reports today register complaints about weekly breakdowns, queuing for hours and similar problems (cf. for example, ROK 1977, GOE 1976). Reliability would give very high rates of return, both in cash and probably also in health, as unreliable supplies make people go back to traditional and polluted sources. Some operational difficulties seem to stem from the view that once a project has started operating, return on finances will automatically be there. This is, of course, not the case.

Queuing and other inconveniences may also be traced to the staff situation (Watt 1978) and the limited working hours for staff, which created a black market in water (GOE 1976).

Recurrent finance and administrative bottlenecks have been mentioned. Other management disorders occur because the Water Department does not control its own accounting, revenue policy and execution is inadequate, office accommodation unsuitable; there is a staff shortage and there is a distinct difference between the design and construction department and the operating ones. There is generally inadequate liaison between departments, provincial and district organization is deficient and a marketing service backed up by research is lacking. This example from a recent evaluation of some Kenyan programmes is probably fairly similar elsewhere.

> "If operation charts are not thoroughly checked, if meter readings are not queried, if reports are not evaluated, if requests for spares are not heeded, there is likely to be a progressive deterioration in the standard of work which will soon be reflected in the level of service. A similar argument applies, if vandals go unpunished, if rate defaulters are not prosecuted or if illegal connections are not disconnected. It is considered that the burden of operation and maintenance is of an entirely different order than the workload for which the current management system was devised." (ROK 1977).

The same types of problems are emphasized by Chaturvedi (1976) in a discussion on water problems in India: The water supplies required for domestic purposes are very small compared to agricultural requirements. The technology is well known, but the application is dependent on *institutional factors* and social attitudes, and is related to developments in allied areas. Although legislative and organizational restructuring is badly needed, it is not enough. Equally important are changes in the attitudes and capabilities of the personnel involved. The present colonial bureaucratic approach with its inadequacy in technological capabilities of personnel at all levels and in all branches of activity has to be replaced by a competent, professional and committed approach. The present approach influences badly also the utilization end, where the inefficiencies are understandable in view of lack of institutional development, policy-making capabilities and authority at the village level. The water user is still the marginal man, "long out of sight in the context of the feudalistic colonial heritage of society".

In Thailand, a survey in 1971 by students of the Asian Institute of Technology showed that 69 of 79 rural water supply systems studied had some operational difficulties. Among the more frequent complaints were: (a) continuing difficulty in collecting money from consumers because of broken taps, great distance to public fountains, and the low incomes; (b) operator salaries too low to support families; (c) pumps or public fountains broken and batteries not charged; (d) inadequate tanks or water sources; (e) insufficient piping to extend the distribution system; (f) lack of knowledge about system operation and chemicals; and (g) a lack of assistance from the central water supply authority (Saunders and Warford 1976).

The case is typical of conditions elsewhere; the variation is only one of degree (WHO 1977, Åhman and Rosenhall 1978).

As is the case in South East Asia and in Latin America (Donaldson 1972), it seems evident that responsibility for operation and maintenance should be decentralized also in East Africa (Schultzberg 1978). There appears to be a distinct relationship between local commitment, i.e. willingness to contribute towards development, operation and maintenance, and the success of programmes. However, decentralization is not enough. In Tanzania, water-supply projects are executed by regional authorities, which are extremely difficult to manage due to the scarcity of financial and manpower resources. One example is the already mentioned Dutch shallow-well programme in Tanzania, which is bound to fail for the following reasons:

(a) The organizational set-up of some 200 people has little chance of being incorporated into the local organization of the Ministry of Water, Energy and Minerals, because of lack of funds. The annual budget of the Regional Water Engineer is so low that he cannot construct more than a few deep wells per year and has difficulty in maintaining the existing wells. It is quite out of the question that he take over the costly Shallow-Wells Project and add it as a new division to his modest organization.

(b) Most of the personnel had to be recruited locally. They had little or no education and had to be trained from the very beginning. Some of the Programme Sections therefore require regular guidance and control.

(c) To keep the machinery for the construction and operation of wells running, the Dutch team could use special methods, for example charter flights to import urgently needed equipment. The local project staff will probably not have these possibilities in the future.

(d) Safeguarding the quality of the drinking water requires seasonal checks on all wells, which in turn requires skilled personnel, materials, and transport facilities. The fiscal implications of this work are such that there is little hope that it will be done.

Thus, the operational problems are mostly traced to management defects and to deficiencies in organizational pattern, institutional framework, administrative procedures and financial planning. One further problem connected with administration must be mentioned: communication within the water administration and the relation of operating experience to planning and administration.

Most ministries have, of course, a hierarchical organization based on districts, provinces and headquarters. Information is passed up in the hierarchy: orders are passed down. Ideally such orders should take into account the experience passed upwards. Water management seems to be characterized by insufficient flow from operators to higher levels of management and absolutely no response back to the field level.

Indeed, as Ian Carruthers has said, there seems to be no incorporation into the planning process of some obvious lessons from the operating experience. It is suggested that one reason for this is that the main participants — both donors and recipients — do not really want to know the outcome of their plans. The planners are interested in aid flows and at present aid flows are determined by criteria related to the apparent quality of the plan document rather than to operating efficiency of previous projects (Carruthers 1976). The gap between the ideal and the real, between plan and reality is very apparent. It can be seen in any of the *sectorial plans* where focusing on one sector also narrows the opportunity of planning for reality.

Sectorial planning forces decision-makers to look at water as a water planning problem only and prevents them from looking at it as an agricultural problem or a health problem. At the same time, health planning is marginally concerned with water for agriculture and agricultural planning is concerned with the provision of water to the fields and is not concerned about hydroelectric power or health problems.

An important administrative problem is, of course, finally, the fact that administration of water supplies — as indeed the administration of irrigation — is divided between ministries. Some pumps and installations are under the Ministry of Health, as they have been donated by UNICEF; others are under the Ministry of Agriculture, because they administer the resettlement of families; other installations are handled by the Ministry of Water Development. There is a definite need for coordination on the district level, which, for example, has been tried rather successfully in Kenya. In India, there is a coordinating agency under the Central Health Ministry, otherwise water supplies are decentralized and implementation is handled by different agencies at State level — in certain States, there is even an independent department for the rural water supply; in others, it is handled mainly by an engineering department.

As many as seven agencies are currently responsible for water and sewerage services in Nepal, despite the limited funds available. In Sri Lanka, a national water supply and drainage board has taken over the responsibility from the earlier multiple agencies. In Thailand, six principal departments in three ministries are dealing with rural water supplies (WHO 1977).

(e) Local participation

Why is it that some taps are further away from the village than the river? Why is it that some boreholes are drilled in places where the villagers spend only six weeks a year? Probably, because the villagers have not been asked. This is a common feature of regionally or centrally based water programmes organized by a government and paid for with experts, goods and funds by a donor. The public is not asked.

Consumer participation seems to be a crucial point in efficient rural water-supply systems. Lack of participation of citizens is cited as a reason for the chronic deficit in water-supply systems in Latin America (Pinto 1972). In March 1979, the WHO International Reference Centre for Community Water Supply published an interesting and worthwhile literature review on participation and education in community water-supply and sanitation programmes (Van Wijk-Sijbesma 1979). The disappointing results of many water-supply and sanitation programmes can often be attributed to the lack of community, understanding and participation (Pacey 1978, Stromberg 1978, UNICEF 1979, Hessing and Kerkhoven 1978).

We may venture some explanations why it is so:

- If people feel the need for a utility such as a well or a borehole, if they plan or participate in the planning of the utility, if they form some kind of cooperative to pay for it or for someone to look after it, it is certainly possible that it will be kept up. Everyone feels a responsibility for the utility and knows its usefulness. It is also highly questionable whether outsiders can impose and bring about consumer participation (or for that matter income distribution). But these are commonplace observations.

- Public participation, of which we talk much and have many convictions but rather few facts, is something which really is in need of research and which is eminently researchable as is shown, for example, by Mbithi and Rasmusson's study on the Kenyan *Harambee* movement (1977). A series of papers have emanated from the OECD Development Centre on public participation and self-help in connection with water supplies which have been summed up by Duncan Miller (1979), who also provides a short reading-list on the topic. He discussed participation as consisting of three components: (1) Participation in decision making from the outset of a plan, programme or project. (2) Participation in the implementation of action(s) decided upon above: this means action involvement in terms of self-help labour provision of local building materials etc. People are usually more willing to give time in working, rather than to provide cash which sometimes is difficult to collect (Feachem *et al.* 1978). Public participation is often, however, reduced to the provision of manual labour. (3) Participation in the sharing of benefits to be derived from the action and the costs of undertaking the actions, an equitable sharing of benefits and burdens (Miller 1979). The importance of community choice and the community decision-making styles and institutions have been stressed by Whyte and Burton (in Feachem *et al.* 1977) and the effectiveness of local institutions by Cairncross *et al.* (1980).

The problems of how to bring the public into the planning process are formidable and politically difficult issues. For some, it has been so formidable that they prefer to build, design and plan without the interference of local people and design regional programmes without local dependence (in discussion, Burton 1974, p. 72. It is interesting to consider this type of policy in connection with the unsatisfactory situation brought about by central planning, expatriate consultancy firms and the "neat assistance package" idea of foreign donors).

Some people have looked at local associations in connection with fee collection and similar activities. But if there are no formal routines for cash collections, fee collections and such things, there will be difficulties. In Ethiopia, there is no lack of examples of successful farmers' associations for school buildings, rural roads, and dams. The Kenyan *Harambee* experience shows that there can be tremendous enthusiasm for such programmes (Mbithi and Rasmusson 1977). But problems turn up in the management of such schemes, independently of whether they have been planned locally or not. Guidelines and manuals are badly needed, as are educational activities. As it is now, local responsibility seems more formal than real. "As it is now, nobody on the local level seems to know anything about anything" (GOE 1976).

The above discussion has as its point of departure that funds for water installations and the construction of such installations are organized centrally, whereas O and M are a local responsibility. It is, of course, also possible to organize funds and construction capacity are organized locally, and let the government or the central authority look after the O and M. Sometimes, this would certainly be preferable: it is, maybe, easier to mobilize local efforts for the building of a utility which will be ready after some time, rather than ask the local community to take on an O and M task which will never end. It is also

probable that the planning inputs are easier to organize in such a case. There are also other variations and options for local level organization:

(1) Ownership by the water agency, with or without water charges.

(2) Ownership by the water agency, with some management power delegated to a village-level management committee.

(3) Ownership by private individuals, with charges to members of the public.

(4) Ownership by a water-users' association, from which non-members may be excluded.

(5) Ownership by the local community, where this is a corporate body.

(Cairncross *et al.* 1980). The features of these systems in terms of ownership and responsibility are shown in Table 3:4.

(f) Sanitation

Several conferences have recently emphasised the importance of sanitation as a part of rural water-supply programmes (Pacey 1978; The Engineering Science and Medicine in the Prevention of Tropical Water-Related Disease, London 1978). The Canadian International Development Research Centre (IDRC) has published an annotated bibliography of low-cost sanitation technology (Rybczynski *et al.* 1978). Two excellent recent volumes deal with "the faecal peril" and waste management: *Water Wastes and Health in Hot Climates* (Feachem *et al.* 1977) and *Community Water Supply and Excreta Disposal in South East Asia* (WHO 1977).

The connection between improved water supply and its impact on health is not well understood. Nor is the connection between improved sanitation and health. The reason for this is that, as Saunders and Warford put it, the water supply-health relationship is highly collinear with a variety of economic, environmental, social and cultural factors, the effects of which are difficult, if not impossible, to isolate. Measurements include the discounting of changes in expected life-time earnings based on the dubious assumption that the economic output of humans reflects the value of life and health and that the life-time earnings can be measured (Saunders and Warford 1976, URT 1979).

There is some evidence that improvement in sanitation, in the long run, is more effective than vaccination against diseases such as cholera and typhoid (Cvjetanovič 1978). For other attempts at causal understanding cf. Bradley (1978) and Freij *et al.* (1978).

A technical aspect of this problem is, of course, that sanitation installations must not contaminate or infect the sources of household water supplies. Much thought has gone into the planning and construction of sewerage systems based on water and on various ways of decontaminating or purifying sewage before it is discharged into a river or lake. Less known is the problem of infiltration into the groundwater and into wells of faecal material from latrines. Highly permeable soils or cracks in the bedrock may permit contamination over quite substantial distances (ROB 1977).

TABLE 3:4

Types of organization	Key requirements				Cost	
	Construction	Maintenance	Access	Motivation of manager	To authority	To user
Water authority — with water rate	Direct employment or contract: construction may be efficient, but expensive	Routine maintenance possible at a cost	Open to the public by right	Bureaucratic	High cost, but offset against the prospect of recurrent income	User faces recurrent charges that will be substantial in the case of small supplies
Water authority with some management delegated to local individual or committee	Community participation in fund raising and in construction can be organized	Some local maintenance or "first-aid" repair can be institutionalized, but responsibility rests with water authority	Open to the public by right	Local "managers" receive some kind of reward	Initial cost may be reduced but recurrent costs must be met	User pays through participation, thereafter only indirectly through taxation
Private supply or institution supply with access to public	Private; no administrative involvement	Private; no administrative involvement	Access by payment (per container or per month)	Interests of owner/user plus possible profit in some cases	Some subsidy may be necessary to secure standards and to secure access for the public	Commercial fee unless there is private or public subsidy
Water users' association	Association constructs with some technical assistance	Association responsible for maintenance	Access to members only	Corporate interests of members plus token share of dues	Initial capital grants and supervision costs	Routine payments of dues to cover costs
Very local authority or commune	Water supplies constructed as a communal facility	A routine activity for a work team or department	By right of community membership	Water management one of several functions	Grants and supervision costs	Costs met out of local tax or in a commune, production profits

Source: Feachem *et al.* 1978.

Health benefits from sanitation are not immediately evident and therefore sanitation problems have not been properly assessed. Some general benefit may be obvious, but past attempts to justify sanitation in terms of health benefit to cost ratios have not been successful. Few serious studies have been undertaken on the effects of sanitation on the health of the population served (Pescod 1978). The problems concerning sanitation are similar to those of water supplies: it can be maintained that one has to have a sustained effort to mobilize local participation in the design, planning implementation and operation process. Another problem is to accomplish this.

Understanding and acceptance are essential guarantees to water supply and excreta-disposal programmes. Historically, the reverse assumption was frequently dominant. If the facilities were provided, people would use them (Wolman 1978).

A smattering of an insight into consumer behaviour theory would have made such arguments invalid. Water habits and sanitation habits are not the result of ignorance. However, most often, the solutions offered for a problem of this type are more education and more technical facilities. It is our contention that the technical facilities and solutions the western world has offered (such as water-based excreta-removal systems) are neither useful nor appropriate.

In this context, we are interested in the operational problems of sanitation programmes. There is a difference between rural and urban water-supplies. In sanitation, this difference perhaps also exists, but the main difference is between communal facilities and private facilities.

Sanitation facilities for large villages and rural communities are usually not based on water-borne sewerage as are the urban, but they are also treated as avoidable financial burdens to the community. Any management system of such facilities must in detail define individual and institutional responsibilities such as intervals for emptying, responsibilities for cleaning and other tasks to be done, etc.

Often such responsibilities are not defined; and many sanitation programmes have failed precisely for this reason.

Of the rural sanitation needs, programmes for large villages and conglomerations of people are the most urgent. If people live scattered over the countryside, the management problem is usually not urgent; sun and microbiology do their jobs. However, educational programmes, and programmes for pit latrines and other types of excreta-disposal arrangements need a rather extensive management input.

(g) Re-use of sewage water

The re-use of sewage water (or rather the conscious re-use) is a prospect for the near future. In Europe, most surface-water sources for drinking water are in fact treated sewage water. Today it would seem that only the Windhoek water reclamation plant in Namibia produces drinking water through direct re-use of — as the current euphemism goes — reclaimed water (Isaäcsson *et al.* 1978).

Such procedures, although technically feasible, are probably unnecessarily complicated and expensive for developing countries to operate. They are also based on the idea that waste has to be carried by water and, as Stoner says (1977), means that we are "taking a clean valuable resource — water — and a potentially valuable resource — human wastes — and mixing them together to pollute the water and make the fertilizer qualities of the excrement just about useless".

The use of raw, or somewhat treated, sewage water for irrigation has been suggested by several authors and is practised in several places (Goldberg 1976, Parker 1978, Lvovich 1973, Stander and Clayton 1977).

The main operational problem here is the constant problem of risks. It is easy to transmit agents of disease to crops and vegetables and thus to humans, if the management controls of the water quality are deficient. There are also the health risks for those who handle this type of water and further risks for polluting groundwater and rivers, salinization, etc. (Rybczinski *et al.* 1978). A further risk in the operating of sprinkler systems with sewage water is the aerosol effect downwind of the sprinkler and the risks of spreading disease agents over a large area (Katzenelson and Teltch 1976, Shtarkas and Krasilshchikov 1970).

(3) Irrigation

(a) Introduction

Irrigation is provided in a variety of physical systems. All such systems have some common recognizable components:

Acquisition, which may involve diversion of gravity flows with or without ponding or damming, and lifting river or ground water.

Transport through canals or pipes to the area of use.

Distribution over irrigated fields by flooding, field channels or water courses, sprinklers, drip-by-drip plastic piping or some other equipment.

Drainage of excess water, is a necessary but sometimes not recognised component.

In comparison with rural water supplies, irrigation is a major user of water. Chaturvedi estimates that of water for human use in India up to 94 per cent is used for irrigation purposes (Chaturvedi 1976).

Irrigation exists in a variety of systems. There are the very large canal irrigation arrangements of, for example, the Indus Valley and North Eastern India. 75 per cent of the agricultural land in India is, however, not irrigated in this way but either used for only "dry" or "rain-fed" agriculture with different mixes of additional irrigation or "rain-water harvesting". There are small scale irrigation systems on a family or village base and there are a variety of sizes of groundwater-fed or tube-well systems. There are also combinations of groundwater and surface water in conjunctive use for irrigation.

Irrigation is introduced or used for different reasons. The main reason is, of course, to improve total agricultural output in areas of erratic or low rainfall or to grow crops like rice which depend on large amounts of water during part of their growing season. There are also other reasons for establishing irrigation schemes. For example, there is no evidence from the past history of irrigation projects in Kenya that they can be justified on economic or financial grounds as many schemes even fail to recover their recurrent costs (ROK 1978d). Irrigation schemes are therefore justified on social or political grounds: to provide land for the landless, create job opportunities and alleviate poverty among the landless. However, it is a moot question whether such schemes can, except for a short time, alleviate population pressure or unemployment.

There are, of course, a variety of technical and agrotechnical problems involved in the construction and operation of irrigation. However, it has become more and more evident that social, human and cultural factors play a decisive role in the success of irrigation, as they are reflected in political, economic and management problems. Technical problems can also be discussed in terms of social problems, for example:

(1) Transit losses due to leaking water channels are very common. Water which seeps from a watercourse does not disappear since it goes into the groundwater and is available for re-use. However, to a farmer further down the channel without a tube-well and without adequate supply from the water channel, the water is lost just as if it were piped to the sea (Corey and Clyma 1975). This farmer suffers from an inadequate water supply, whatever the benefits someone else gets from the seepage water. His interest in the operation of the system and the maintenance of channels is obviously more acute than the interest of those higher up in the channel, or those who have afforded to drill tube-wells. Difference in access to utilities due to differences in income is thus exacerbated by seepage.

(2) Or, to take another example: the determination of appropriate water applications for a given soil type and a given crop pattern in a new scheme is a major problem. There are problems in defining the properties and the hydrological characteristics of the soil, the probabilities of rain, the effects of different combinations of water application in time and volume, the water quality, the impact of disease vectors. But in the end, there is a person who is doing the work and the daily behaviour of farmers and their cultivation methods or their management capacity is equally important.

The following discussion will mainly deal with irrigation as organised in some form of a system and not so much with rain-fed agriculture with additional irrigation. One reason for this is that the institutions connected with irrigation are easier to look at whereas rain-fed agriculture can have almost any type of organization. Problems of irrigation institutions are easier to identify (AAU-ODI 1977, Taylor and Wickham 1979).

However, water control on rain-fed land is of utmost importance. Rain-fed savanna areas constitute a large agricultural potential. Population increase forces farmers out to marginal lands, causing serious soil degradation due to heavy pressure on sensitive soils. Problems are very acute and research at present inadequate. Degradation in flat areas is slow, in steep areas rapid. Countermeasures against soil degradation can therefore give bigger returns in steep areas, where improvement is easy to demonstrate to the population. In rain-fed areas systems have been developed for water harvesting (e.g. India in combination with contour ploughing) and arrangements made for supplementary irrigation to reduce risks. Machakos in Kenya is an example of an area of irreversible soil degradation.

One important aspect when discussing irrigation is the difference between countries and indeed continents. Difference in land ownership creates different efficiency and management problems. So, for example, in the Indian situation the farmer usually owns his land (for the moment we disregard the often occurring case that he has "lost" it as a security for a loan which he can never pay back) and in principle he decides what to do with it. There are, of course, certain restrictions concerning crops, concerning water allocation and rationing, there are applications and permits. But many decisions remain with the farmer and he can usually sell his produce on the open market. For historical reasons, the African situation is completely different and another distinctive type of irrigation scheme is more prevalent: the planned settlement scheme, on earlier unirrigated land. The settlers are tenants, the management decisions about cropping patterns, water allocation etc. are taken centrally; they are operated as an integrated management closed system. The central body provides agricultural inputs and recovers their costs by deducting them from the value of the marketed crop. Such schemes are, for example, Mwea and Perkerra in Kenya, Gezira, Galole, Khasm el Girba in the Sudan etc. (Chambers and Moris 1973, Ruthenberg 1974, Gitelson 1971, Baarspul 1971, Thornton and Wynn 1968, Carruthers 1969, Sörbö 1975, Götz 1969, Barnett 1977, Hyderabad 1978, El Kammash 1974).

We have already referred to schemes which are justified on other grounds than purely economic ones. Such schemes are found mainly in Africa. In the context of this volume, it is interesting that such schemes develop other patterns of conflicts than the Indian or South East Asian. In the latter schemes, conflicts between farmers and between rich and poor are more pronounced, whereas in the schemes with integrated management systems the conflicts between tenants and representatives of the administration and government are more exacerbated.

The following discussion will deal with problems of efficiency, of administration and management, and of relations between farmers.

We are in great debt to Anthony Bottrall who during recent years has spelled out in detail many problems connected with management and administration of a variety of irrigation systems in India and elsewhere (Bottrall 1978).

(b) Problems of efficiency

Introduction. Much of the discussion, whether in terms of operation and maintenance (O and M) or of water-allocation, is based on an idea of efficiency, and the problems are formulated in terms of how they affect efficiency. There are shades of difference in the definition of efficiency. Some authors make a difference between efficiency and effectiveness. Efficiency is closely associated with the idea of productivity, that is between the results or achievements and the costs or sacrifices needed to achieve the results. Effectiveness is used when comparing results of an activity against goals and aims, often of a higher order such as social justice, equity etc. The smaller the margin between the two the better the organization.

A one-sided interest only in efficiency problems or productivity problems may result "in a better performance of the wrong tasks", as it is possible to be efficient without being effective (Widstrand 1972). So efficiency is not only a question of retaining surface water in suitable areas and transporting it with minimum losses to places where it is consumed, but also a question of the objective of the irrigation system. No absolute technical standards can be set up, because practices which are technically inefficient may be judged to be acceptable in view of social objectives (Harriss 1976). We shall not dwell long on the semantics of efficiency but rather discuss it in terms of operational efficiency and water utilization efficiency.

Operational efficiency: general problems. There are obvious problems in measuring or estimating operational efficiency. A comprehensive measurement may be attempted in either social or private cost/benefit terms where irrigation is treated as one of an array of inputs.

All cost/benefit analysis is subject to many problems of estimation (de Maré 1975). The time dimension is especially difficult in irrigation schemes since the incidence of costs and benefits tend to be assymetrical — costs occurring in the beginning of a project, benefits accruing over a long time. As the measure of performance is highly sensitive to changes in discount factors these become most crucial to the over-all estimation of efficiency.

Calculation of return of investment seeks to focus attention on the productivity of the irrigation element itself. But still unanswered are the questions:

If performance lags behind intention, is this the fault of
- over-all design?
- detailed operation?
- structure of institutions?
- internal design?
- decision-making? (Thornton 1975)

Narrower in scope is another criterion which may be useful in some circumstances: the value of net output per unit of water used, either total or for a specified period of the year. Such measurements of efficiency are important where water is a limiting factor to production. For example, in the Dry Zone of Sri Lanka it is more realistic and more useful in determining policy to consider returns of water than returns of land (Chambers 1974, Levine and Wickham 1977).

Water administration efficiency is a term used by Thornton (1975). It has been little studied (cf., however, Mellor and Moorti 1971). It hinges on (1) the quality of manpower and adequate technical knowledge at relevant levels, (2) strength of morale and commitment at various levels of attitudes towards achievement, and (3) efficiency of two-way communication between the public body and farmers (Levine *et al.* 1973 and Davey and Rydzewski 1976).

We have chosen to bring out a few problems only for discussion. As this is a survey of knowledge and non-knowledge we would like, already in the selection of themes, to pin-point areas where more knowledge and, of course, more research is necessary, or, rather, more research of kind other than that which is prevalent: what is required is less single-discipline research, but more multidisciplinary investigations.

Different kinds of problems occur, of course, at different levels in the transmission system: problems at canal level are different from those at the farm level. There has, according to some, been a tendency to focus too much on farm-level problems (Takase and Wickham 1976, Lazaro *et al.* 1977). On the other hand Lowdermilk's works, and other studies in the Colorado State University projects in Pakistan, show that many of the problems really exist at the farm level, but had been disregarded because of earlier mistakes. Figures showing unrealistically high water-efficiency rates in the fields were used for many years and turned the research interest away from the field level.

Problems of unpredictable water supplies. The traditional use of water depends, of course, on a predictable supply. It is well known that the more sophisticated crops or high-yielding varieties (HYV) one uses, the more precision is needed in the administration of water to the fields, both in time and in volume. But also for non-HYVs, a regular water supply is the most important factor determining crop yield and crop selection.

This has been shown for Pakistan by Lowdermilk *et al.* (1975), Freeman and Lowdermilk (1976) and for India by among others Moorti and Mellor (1972), VanderVelde (1971), Hodgedon (1974), Reidinger (1971), Ellman (1978) and Miglani *et al.* (1975). Valera *et al.* (1975), Wickham (1973), Le Ngoc and Wickham (1972) and Kikuchi *et al.* (1977) have discussed this problem from experience in the Philippines and Small (1973) and Tantigate (1976) from experience in Thailand.

One main problem for irrigators is that the supply of water is unpredictable and the unreliability of water supply is considered by many to be the main problem of irrigation management (Valera 1976, Thronton 1975, Wade 1975a, Lowdermilk *et al.* 1977, Corey and Clyma 1975, Sivanappan 1977, Barnett 1978). Thus water control at the farm gate is a decisive factor in irrigation efficiency and water allocation should be a main theme for research and investigation.

There are, of course, many reasons for unreliability. Some are connected with technical problems such as seepage, non-maintenance, storage problems etc. In the big river-fed canal systems rainfall or lack of rain is not a great problem, but more so in monsoon-dependent systems. Pump failures, short running hours and such problems befall tube-well schemes. But most of the unreliability problems

have their origin in management and administration of the system, and in deficient institutions. They show up as a low intensity of cropping.

Why is intensity of cropping so low in irrigated areas? Because farmers adopt strategies which lower uncertainties but also lower maximum output (Wade 1975a). Some tube-well projects show a dismal record. Bhuiyan (1977) has shown that tube-wells which have capacity for 60-100 acres of rice at times only are used for less than four! Underutilization can be real or disguised and depends on a variety of factors which again show up as unreliability of water supplies.

So, for example, economic assessments of a project may not be sufficient to show what will happen. Costs may be underestimated and capacity overrated for political reasons to satisfy the wish of politicians to expand the project outside what is economically feasible.

Rational principles for the allocation of water may be set aside in projects which have other aims than irrigation, for example generation of hydroelectric power. If there is a balance between the interests of industry and agriculture in relation to the use of available water, decisions tend to favour the interests of industry — and cause unreliability in water supplies which then looks like underutilization. Farmers who get access to water may change their agricultural patterns and start growing sugar or paddy or some other water-demanding crop. The total amount of available water does not suffice to satisfy these new demands, and water supply becomes unreliable. Wrong planning decisions or assumptions about future water use or unpredictable changes in agriculture again look like underutilization (Jacoby 1976). There is, of course, also a real underutilization when the equitable usage of water is prevented. Jacoby mentions the Ganges-Kobadak system in Bangladesh where underutilization was caused by fragmentation of land into small pieces and thus caused costs for water channels to rise and increased water unreliability. The bigger landlords did not extend or increase their crops because of fear of taxation or land reform.

Unreliability of water supplies may thus have many explanations besides the more common ones of overwatering at the head of the source with ensuing problems at the tail end, non-optimal use of water, or keeping the storage in large dams to have excess storage capacity in case of floods.

Administrative problems. Recent studies on irrigation return again and again to the problems of management. Robert Wade, J. Harriss, Robert Chambers, Richard Reidinger and Anthony Bottrall have written at length about various management problems (cf. Bottrall 1978). A tendency of all these writers has been to put an emphasis on the day-to-day management of irrigation at various levels in the hierarchy. Most deal with canal systems in Northern India.

Such management studies are now in their infancy, but there are some generalizations which may be interesting to mention. Management of an irrigation scheme can be looked upon as an evolutionary process, where at the beginning of new projects much more stress should be put on discipline in the best sense of the world. Especially, in large systems or projects, discipline (in handling water, in allocating water, in collecting fees, in looking after installations) is crucial to the success of the scheme. There is much discussion in plans and similar documents of management and mention of "good management" as a necessary prerequisite for the success of schemes. Usually "good management" is not defined but probably means top-level management of some quality. There is obviously a need to redefine the meaning of "good management" *and* to widen the concept to embrace the whole management structure. We have very little information on the middle-level personnel, those who manage those who manage water (Chambers 1978).

Obviously, there are different administrative problems depending on the size: whether large-scale canal, minor irrigation-tank schemes, tube-well schemes (which tend to be small-scale) etc. The main aim of all such schemes, however, is to have *less water losses and higher cropping intensity*. Thus, in all these types of irrigation, water allocation is a central issue (Bottrall 1978). The way water is allocated and the constraints in allocation point the way to other weaknesses in administration and problems ensuing from such "soft spots". Here again, there is ample scope for research.

The large scale administrative structures also need to be looked into. There has been a trend towards consolidation and merging of agencies operating in irrigation within the same administration, but numbers are still astonishing (Bhuiyan 1977). In Sri Lanka, the Ministries of Irrigation, Lands, Agriculture and Mahaweli Development plus the Mahaweli Development Board and the River Valleys Development Board are all concerned with irrigation planning and management (Perera 1978). Other astonishing features are that in the Command Area Development Projects in India, the department of Irrigation is *not* under the Command Area Development Authority in some States. It is obviously a key department, but cooperation difficulties between departments have their roots in a long history of grievance and competition between departments in the Indian Civil Service.

The Command Area Development (CAD) is otherwise an interesting development, where attempts are made at the State level in India to bring the departments involved in irrigation under the same authority. This authority is either an authority in the real sense of the word or has only a coordinating function and/or an advisory capacity. A number of fundamental questions still remain for CAD to solve, for example, whether a CAD Authority is needed in all circumstances and if so, what sort of administrative linkages is required at different levels, the problems of securing loyalty of staff to an organisation like the CAD to which they are only temporarily seconded from their parent departments, etc. (Singh 1978).

In the African context, irrigation departments are "naturally" subordinate to agriculture or a parastatal, like the Kenyan National Irrigation Board. Regional coordination and authority is also better developed than the line department structures, at least in theory.

There is an obvious need for management guidelines, based on research, knowledge and a rationale for choosing the appropriate management methods. Current recommendations and/or decisions are based on a very "crude and perfunctory reasoning" (Bottrall, *passim*), particularly, recommendations about institutions for agricultural development intended to improve access to the rural poor. In fossilized administrative systems, and in "centralized" democracies, be they dictatorships of the few or of the masses, the decisions of individuals are circumscribed, room for manoeuvering limited and personal incitement for initiating change low. It is in such cases easier to act according to some historical precedent: "we have always done this", than to think in terms of efficiency and reconstruction.

Manuals and guidelines could help solve the problem of visiting experts suggesting some procedure or institution they saw at their last whistle-stop and which seemed to work there. The "automatic cross-cultural transfer" does not only operate in the North-South direction ("climatic bias"), but also sideways, if the expression is permitted. Procedures which work on Taiwan are suggested for Java or Ceylon, "after all, they are all Orientals and grow rice", being the underlying, but maybe not overtly expressed, argument. We shall deal below with one such question, "What can we learn from China?", in connection with a discussion on farmers' association.

Good management needs people with ability and with different types of skills. Anthony Bottrall (1978) has outlined a variety of management situations, different needs in a project and the skills which are necessary to match such needs. Such a match is badly needed in order to understand the diversity of management in empirical situations, but also in order to establish some formal principles: after all, there are but a limited number of significantly different techniques for attempting to optimize the match between water supply and demand on surface-water delivery systems (Bottrall 1978a).

Problems of information and education. For many years, we have heard that one solution to the ills of this world is more education. Especially, the peasantry should be educated in more rational and more productive ways of agriculture. Elsewhere in this volume, we discuss the problems of agricultural extension and the generally very low competence in such services. We also discuss the concept of the farmer as an idiot, who must be brought around to mend his ways and do as we tell him. Blatant examples have been the very low educational impact of institutions like ICRISAT or the unnecessary stupidities of the low-level bureaucracy in the Tanzanian *ujamaa* enforcement period in the middle seventies.

There are, of course, quite a few things that have to be at least talked about, like the use and usefulness of clean water, the connections between water and disease, efficiencies in water use, *et cetera.*

However, the mere calling for more technology and more education will not help: there are maybe some lessons to be learnt from the people themselves, from the people who have lived with the ecology and the land for many generations. A problem is often to find out about local knowledge and another problem is, of course, the experience (to many humiliating) that experts may learn something from the common man.

The incentive to learn is lacking in bureaucracies where personnel promotion is strictly limited to seniority with utter disregard for capability (Chaturvedi 1976). Spending more time with the peasants and getting better acquainted with their problems both increases the transfer of knowledge and makes for more realisti solutions to problems (Tschannerl 1975, Widstrand 1978b).

Another educational aspect which concerns irrigation management is the dearth of people and educational institutions which will study irrigation in a wider context than only the technological (Chaturvedi 1976). Furthermore, in some countries even the engineers do not exist, or, those who are there can choose from a rather wide selection of more attractive jobs than irrigation management. This again concerns the education of engineers, the capacity of universities and in the end the causal chain brings us back to problems of mathematics teaching and competence in the schools. It is not that easy to call for more education.

Problems of recurrent finance. Money is usually available from donors for the construction of new schemes but, as is the case in rural water supplies, funds for recurrent finance are supposed to come from revenue, fees or from the recipient government.

The main activities for which funds are necessary are silt clearance, weed clearance, maintenance of irrigation structures and measurement installations. In tube-well schemes, or where water has to be lifted, funds are needed for pump maintenance and fuel. The requirements differ from scheme to scheme (Hyderabad 1978).

As funds lately have been made available on favourable terms for rehabilitation of schemes there is the possibility of deferring current maintenance expenditures and absorbing the costs later as rehabilitation investments. (Lazaro *et al.* 1977).

Periodice cheap sources of credit would then substitute for government expense in scarce annual budgets. This assumes that such sources will be available also in the future.

Problems of recurrent finance are always intimately connected with problems of water charges and their collection. Water charges usually do not follow the general rise in costs for operation and maintenance. This creates new problems: the irrigation department, which at one time set the prices according to the then current costs for operation, now has an income deficit and has to cut down on the work which they should perform. The low costs of water will not prevent farmers from overwatering. The optimal use of water is further prevented by elaborate ways of setting charges and organizing collecting procedures in many places (Bottrall 1978).

Farmers' associations. Any discussion of management objectives and management will automatically lead to a discussion of the relations between farmers and bureaucracy, and of farmers' organizations. We have decided to take up the relation between farmer and government/bureaucracy in Chapter 5 on conflicts, as the relation is often not the best.

Relations between farmers are also conflict ridden and some discussion on conflicts within the farming society, between rich and poor and between farmers themselves will be discussed in the chapter on conflict.

Farmer groupings, however, will be discussed here as associations of a variety of kinds, and are suggested as solutions to some management problems in irrigated agriculture. There are two major pitfalls in the discussion of such associations.

(a) the belief that *traditional groupings* and institutions in a cooperative form can be either *continued or may have relevance* in modernizing society;

(b) the belief that types of associations which have developed in one cultural area can be lifted out of context and suggested as a solution in completely different surroundings.

The main arguments under (a) are brought together by Widstrand (1970) in a discussion on cooperatives in East Africa. The main points are that old traditional peasant "systems" of cooperation were exclusive, i.e. they were built on kinship or some such principle of relationship and excluded those who had no such relationships. This was the type of organization for example in the original *jamaa* (Boesen *et al.* 1977) and in the water associations in Java.

Modern cooperatives, like producers cooperatives, the Tanzanian *ujamaa* system, water users' associations etc. are based on *inclusiveness*, and the association endeavours to bring in all who have a common interest in the aim of the cooperative. The aim can vary enormously. In the history of the Scandinavian cooperatives, the main goal for the peasants' cooperatives was to organize small peasants against the bigger landlords and provide cash and credit facilities. In the consumer cooperative movement, the aim was to get the ever-increasing class of industrial workers out of the credit link with small dealers, shopkeepers and economic middlemen.

The combination of old systems and modern cooperatives most often results in one or more splits in the cooperative according to traditional relationships (Hydén 1970, Widstrand 1970 and 1972). Loyalties are still more with the family and kin than with the new group and tend to reinforce the power base of the rich (Hough 1966). Decisions on who gets the scarce supply of paddy bags first and his transport organized are not taken on rational economic grounds. The invocation of "traditional", "old", or even "good old", cooperation can, as in the Tanzanian

ujamaa movement, be used as a politically useful myth; but it is mainly mystifying and tends to paste over class differences and polarization in the countryside.

In some cases, however, traditional systems or local forms of organization have been changed or rather adapted and seem to function well also in handling O and M problems. One such programme is the Thana Irrigation Programme in Comilla, Bangladesh (Coward and Ahmed, 1978). The traditional irrigation system of the Chagga of Kilimanjaro in Tanzania has had some interesting "ideological" input into the modern system of cooperatives which have been very successful (Masao 1974).

The arguments under (b) or rather against the cross-cultural transfer have been voiced most forcefully by A. Bottrall. Water-users associations work very well on Taiwan and the Taiwanese example has been invoked and tried without success in other parts of South East Asia (Wickham 1973). The Chinese example of highly disciplined, concerted community action is another aspect which has fascinated observers. What can we learn from China? This is an enormously difficult question, like the question of what makes society tick and what makes it go in this or that direction. The answers are also many, and have been discussed in a variety of ways by several authors. The water and irrigation programmes are discussed by Aziz (1973, 1978), Vermeer (1977) and Kaul and Kathpalia (1978).

In our opinion, there are two issues which need to be taken into account when discussing China. One is that trying to solve problems of rural water and irrigation is like trying to solve the problem of rural development. In the West, we have had a tendency to sectoralize our research and way of looking at things: medicine is for doctors, pumps are for engineers, irrigation for irrigation departments and rural development for rural development specialists, or in the terms of D. Bradley "vague generalists" (1978). The Chinese way of looking at this is radically different. The main thing has been to create new social relationships and from this base create new relations of production. Sartaj Aziz writes:

> "The Chinese concept of development is not confined to redistribution of land or incomes but visualizes a new social relationship based on shared austerity and greater self-reliance and requires that the process of social transformation of the rural society precede the technological improvement of agriculture (1978)."

The perspective provided by the Chinese on self-reliance resolves itself into a question of achieving political, economic and cultural independence and autonomy of decision-making and management. Nickum maintains that

> "An investigation into the methods and structures of local irrigation management in the People's Republic of China could yield important insights into the operation of a decentralized inter-village form of technically based management which harnessed apparently successfully to the objective of modernizing the rural economy" (Nickum n.d.).

Little has been done in this direction.

It would seem from Nickum's description that many problems in irrigation are the same in China as elsewhere: problems of rates and charges for irrigation water whether by area or volume, problems of relations between peasants, peasant groups and government employees in the irrigation hierarchy, etc. These facts would probably make a Chinese study on management very useful, especially in the fields of conflict resolution.

However, there is the second issue which is more problematic to raise. It has to do with cross-cultural transfer problems again. Even if we learn from the Chinese or Taiwanese, is it possible to transfer this knowledge or the institutions elsewhere? Probably not. There is the long cultural tradition of the Chinese which has made being Chinese something very special. There is the long tradition of irrigation and of industriousness. Joseph Needham writes:

> "The importance of irrigation channels for intensive agriculture water conservancy for preventing floods and canal transport for gathering in of tribute to the Imperial Court from the Provinces led to the establishment of great public works which is absolutely living in China today, as much as it ever was in the Han, Ch'in or Tiang dynasties". (1963).

But there is more in this than historical precedent. One way of explaining industriousness as a part of Chinese culture is also suggested by Needham.

Discussing the absence of dynamics from Chinese physics, Needham refers to the concept of inertial movement, which to the Greeks was an absurdity. A basic tenet of Greek thought was that rest was superior to motion: pure contemplation, motionlessness, was naturally superior to motion, among the Greeks. The Chinese did not participate in this valuation. Admittedly, the Chinese lords and scholars also sat still, while the slaves and the people moved about their work; yet healthier fashions, hard to define with precision, influenced Chinese thought in such a way that motion was regarded as, if anything, superior to rest (Needham 1971).

Needham adds: "One cannot help making a correlation between this mentality and the outstanding industriousness of the Chinese people, itself in its turn surely connected with the garden character of their agriculture." Discipline, industriousness, cultural identity, as well as a political system which in mainland China in the last 30 years has produced for the peasants a measure of economic well-being and a sense of identity and security — admittedly at the cost of some values cherished in the West — are some of the ingredients in this cultural make-up. A comparison with India is close at hand:

> "Since the period immediately following World War II, when both (China and India) won independence, China under Communist auspices has almost certainly done far more to conquer mass poverty than has India, which while it employs socialist rhetoric remains a property-owning republic with capitalist entrepreneurs who, for studied rapacity can probably claim to be the equal of any. But Hong Kong and Taiwan and Singapore have also made progress. All are indubitably capitalist. This experience suggests that it makes far less difference as regards the causes or conquest of poverty whether a country is capitalist or communist than whether it is Chinese or not.
>
> And the latter is an explanation that both socialists and non-socialists would join in rejecting." (Galbraith 1979).

Nevertheless, it is probably true, and a reason why Taiwanese-style water associations or Chinese mass-mobilization campaigns in sanitation will hardly work anywhere else. Therefore, also, comparisons like those between the efficiency of groundwater management in China and Cuba vs. Kenya and Tanzania (*Encounter*, March 1974) are meaningless.

To summarize what we know in this field is not easy. However, it is probably true that:

- simple cooperative organizations for collective actions centred around a small and easily recognizable utility (pump, outlet, etc.) which has a well perceived and well understood usefulness may make collection of fees and contributions in the form of self-help labour easier and may contribute to a sense of responsibility for the operation and maintenance of the utility (Wade 1975, Hyderabad 1978);

- coordination between farmers' associations and government is lacking;

- such associations usually have no authority or legislative back-up to get their decisions accepted (Ellman 1978);

- it is important to understand indigenous forms of collective action before suggesting new types of such actions or new organizations (Lowdermilk *et al.* 1977, Bottrall 1978, Rugamisa 1973) (Coward suggests in a recent paper (1976) that such organizations should be based on the group that uses the same source of water, i.e. channel based. We do not know whether this is true or not, but in large-scale channel systems it is hardly likely that one can manage such constructed groups and there must be some kind of smaller groups already in function (village-based? irrigation *panchayats*? kinship groups? brotherhoods? patron-client groups? caste lines as barriers? cf. Eckert *et al.* 1975));

- groups cannot conveniently be constructed or produced and blanket government decrees to start such groups do not work: see, for example, the "death rate" of government-introduced cooperatives in East Africa. Peasants must know that there is a benefit forthcoming from their participation in such groups (Lazaro *et al.* 1977, Sagardoy 1976). Nevertheless, in Bangladesh, outlet committees or pump groups have been formed, but there is little coordination between them and the government staff (Hussain 1978). In India, farmers' associations have been set up at the outlet level within the CAD programmes. We do not know how they function (Kathpalia 1978). In Indonesia, groups for maintenance and construction are set up by the Ministry of Home Affairs through the local administration (Soekadaryanto 1978). Former farmers' associations in Malaysia were amalgamated in 1973 to form comprehensive farmers' associations. These are controlled by the Farmers' Organisation Authority (Abdullah 1978). We do not know whether improved water management really needs greater participation from farmers.

Maybe the real problem does not exist at the terminal but in the main irrigation system? This is a question which suggests itself after recent management studies of irrigation administration (Harriss 1976, Lazaro *et al.* 1977).

In this connection, perhaps the existing division of power would also be reflected in a water users' association, as is the case in so many other places in the world (Levine 1971). Perhaps some of the things suggested for water users' associations instead should be left to the bureaucracy (Wade 1975). A case in point is the *warabundi* systems described by many authors from India and Pakistan. *Warabundi* is an Urdu word meaning agreement about water schedule. The two systems in the Punjab are (1) *kacha warabundi* which is a system of rotation of water arranged by the cultivators themselves — a flexible system, it can be flexed in the wrong way and small farmers are vulnerable — and (2) *pacca warabundi*, in which water rotation is decided by the irrigation department — this system protects small farmers but is enormously inflexible (Mirza *et al.* 1975, Reidinger 1974). Mirza *et al.* (1975) examined farmers' decisions to switch from *kacha* to *pacca warabundi* and found that the majority of those who wanted the switch were farmers at the tail or the middle and that the *pacca warabundi* reduced conflict, despite

its being inflexible. It is interesting that the petitions for the change to *pacca warabundi* from small landowners had always been cleared with their larger associates.

The main conclusion of this section must be that we know little of the social characteristics of water courses. There is much discussion about the example of Taiwan and Malawi, but few facts exist on the beneficial aspects. Rather than suggest that farmers' associations should be formed and believe that this will solve all problems, more research should go into the social "field" or social "arena" of the water course. The call for more research is of course — next to the call for more funds and more transport — very common in development work.

However, little is known of what must be the government input generally (and not mainly by decreeing the setting up of associations) to get organizations of a given type to work (Wade 1975). We lack methods and we lack a coherent way of looking at such problems. The social field approach and the view of agrarian society as an organized flow advocated by Joan Vincent (1977) and the social "arena" concept (Harriss 1976) may be a useful theoretical approach.

We believe that such studies are necessary before steps to organize collective action are taken (Mirza 1975, and many others).

Water-use efficiency. The efficiency of the use of water in irrigation has its own literature, both technical and agro-technical. Water is being used by the plant and the efficiency is then measured as the percentage of the water diverted from the original source which actually reaches the plant.

Some authors define efficiency as the ratio of the water required by the soil-plant system to the water applied from rainfall and irrigation, which gives you an idea of efficiency. Water adequacy is an index of how adequately and equitably the delivered water has been distributed in the area under consideration (Bhuiyan 1978).

The introduction of more complicated standard calculations has been discussed by an ICID committee on Assembling Irrigation Efficiency Data and is published in the *ICID Bulletin* (ICID 1978). It contains a survey of terminology, suggestions for terminology and definitions and also ways of calculating efficiencies in a way to make it possible to compare data.

We have already discussed administrative and organizational aspects of this issue, but there are also technical and physical aspects to be considered (Thornton 1975). Because it *is* a problem. Irrigation water-use efficiency is very low in almost all areas of the world ranging from below 25 per cent to 70 per cent in the U.S.A. (Langley and Robb 1969, Bureau of Reclamation 1968, Erie 1968). The main losses occur during conveyance and during storage. Conveyance losses can be more than 40 per cent of the water delivered and efficiency may be as low as 25 per cent in earth channels in the farmers' fields (Chaturvedi 1976 and Batra and Easter 1972).

Conveyance losses in the systems dependent on the 10 billion rupee Tarbela Dam are estimated to be of a size corresponding to the content of the dam or 4-7 acre-feet per year (Corey and Clyma 1975).

To take an example from the Indus valley:

The Indus river has 142 million acre-feet available. 86 of 142 are diverted into modern canal systems by dams and headworks. Of these 86 some 64 reach the farm system via some 80,000 separate water courses serving 3.2 million farms on 32 million acres. At the farm level, an estimated 26 million acre-feet are added by 125,000 private and public tube-wells. Of these 90 million acre-feet, however,

35 are lost in poorly maintained earth channels from the public distributary to the farmers' fields. 55 million acre-feet or 1.7 acre-feet per household are thus left for the farmers. Of these some 24 million acre-feet are lost due to field application losses. Thus only 30 million acre-feet out of a total supply of 170 million acre-feet are really utilized (Lowdermilk *et al.* 1977 from World Bank 1976).

Transit losses, seepage, evaporation in irrigation in India and Pakistan have been discussed by many authors (Clyma and Corey 1975, Corey and Clyma 1975, Kikaho 1976, Kinawy 1977, Lowdermilk *et al.* 1977, Kovda 1979, Batra and Easter 1972, Bhuyian 1978).

Countermeasures include lining of canals and channels to prevent seepage, and measures to prevent losses by evaporation from dams. Here, a variety of new technological tricks are being tried, like covering the surface with styrofoam pieces, oilfilms, mirrors, etc.

We shall not go into a discussion of the technicalities but would like to mention some problems.

As K. P. Kannan (1979) has stressed, one may in many cases doubt the technical efficiency of some projects. Even if the designers have been preoccupied with the technical aspects to the detriment of adverse effects of broader economic, social and environmental factors in the formulation of projects, the technical efficiency is doubtful. The reason for this is probably that much of the technical problems experienced really are problems of operation, management administration and other software aspects of the schemes.

Secondly, it has been observed that there is often an inverse relation between water-use efficiency and levels of yields. Wickham and Valera have pointed out that in irrigated farms water-use efficiency was high at the downstream or tail end of irrigation systems, because of scarce and unreliable supply, but yields were low. (Wickham and Valera 1977). There are systems designed to ensure that the weaker sections of cultivators get their due share of water — for example, the *osrabandi* system practised in the Sarda Sarhayak project in N. India (Rathi 1978). But the problem seems to be that there is a diminishing marginal return to the use of water. This in turn raises the question of the optimal strategy in designing and operating systems (Lazaro *et al.* 1977). Wickham and Valera ask what are the trade-offs in total production and equity of distribution between a given water supply to serve a large command area with frequent periods of water scarcity vs. its use in serving a smaller command area in which water is more assured?

(4) Pricing

The economics of water supply have interested donor agencies and receiving governments for quite some time, but there is still a variety of opinions on technicalities such as revenue collection and on the basic philosophy of charging for water.

(a) Pricing of rural water supplies

There are three aspects of water-supply economics: (a) the economic aspect which concerns the problems of the total economic benefits of exploitation of water and of the efficient use of resources, (b) the financial aspects which concern the financing of operational costs, including servicing of loans, and (c) the social aspect, basically concerned with social benefits (Carruthers 1973a).

The obvious problem here is that water pricing is a policy question: is water a social good which should be distributed free of charge, or is it a commodity on which consumers probably set a value and for which they would be prepared to pay a certain price? What price? Saunders and Warford (1976) maintain that assigning a high priority for water service to villages able to pay a user fee at least sufficient to cover operation and maintenance expenses increases the probability that water systems remain operational. The same is the case, if consumers have provided labour or other inputs into a common utility. In the long term, they maintain that the real hope for rapid advancement in this sector is to place increasing reliance upon consumers' willingness to pay for the services they consume. Even in relatively poor areas, people may prefer to have and to pay for a water supply than to have none at all (Bromley *et al.* 1977, Carruthers 1969, 1970).

The problem is that all people already have a water supply and that a pricing policy will again increase the difference between those who can afford a safe water supply and those who have to rely on polluted water. In such cases, there is currently no scientific procedure for making investment decisions, including such about project ranking. "Socio-economic studies" constitute little improvement over engineers' rule-of-thumb judgements. Observations of consumer reaction to the introduction of water charges offers the only useful evidence for this purpose (Saunders and Warford 1976).

Furthermore, there is a need to introduce programmes which do not produce an overwhelming fiscal burden on poor countries with a narrow tax base. Governments have thus been anxious to use opportunities to raise finance and give financial questions preferential treatment to economic ones.

A price on water is thought to contribute to the saving of a scarce product and decrease overwatering, misuse etc. (Idemalm 1978). This is, however, not always the case: the Egyptian example may be mentioned (Kinawy 1977) and the fact that in Taiwan there is no charge for irrigation water. However, pricing can probably influence consumer behaviour and reduce wasteful use of water, but generalizations are difficult.

Charging for water may contribute to a feeling of coownership. However, institutional systems without legal status often do not work, informal systems cannot raise money except on a voluntary basis. The powers of coercion may differ drastically between programmes. Carruthers and Browne (1977) also give reasons for a case for free water from communal points in rural areas: (1) The short-run marginal cost of water is frequently close to zero and even over the longer run it is low. Thus a free policy will be in accord with an economic efficiency criterion. (2) Rural water supplies should be regarded as a social service and the financial criterion should play a secondary role. (3) Merit-want of water may be taken into consideration and governments who consider social elements important in policy formulation may elevate certain goods above the market place. (4) Income redistribution is often a major objective of developing countries (cf. the recent Kenyan five-year plan launched in March 1979), but the redistributive effect of providing rural water supplies is unclear. One way of measuring this is to look at the costs involved had water not been free. Browne (1974) estimates that in rural Ethiopia cash savings are four times the value of the extra Government resource that would be required. (5) Rural consumers receive a low degree of service. (6) The ability of rural poor to pay is low and they will only pay for water when there is no other alternative source.. (7) Revenue is usually small and sometimes equals the cost of collection of such revenues. For example, in Kenya, it is impossible with the current methods of book-keeping to find the real costs of water supplies and the income from revenue (WHO Report quoted by Idemalm 1978).

Advocates of strict financial criteria tend to ignore the low level of rural income, the amenity value and the indivisibilities and economics of scale of water supplies. It is better to have "fewer supplies which are free, but which are properly utilized, than a slightly greater number provided out of the small revenue collection, but which are underutilized with the consequent waste of natural resources" (Carruthers and Browne 1977).

Donors have an important role to play in this connection. Most donors, including the IBRD, demand some kind of rates as a condition for loans and assistance.

In his review of the Saunders and Warford book, Ian Carruthers questions

> "whether the Bank is the proper institution to implement this desirable programme (rural water supply) for, although its heart may now be in the right place, its thinking and actions are still governed by the 'banking-head'. The economic case for improved rural water supplies involves such a long-term perspective that these investments will require a charity rather than a banking perspective" (Carruthers 1978a).

A conflict of rates or charging systems may be solved by practising price discrimination, for example between those with a private connection and those who get water at communal points, as a single tariff does not induce water saving and does not contribute to a social objective. The social objective of a low price for the poorest customers can be met and people with private connections should pay at least marginal costs (Carruthers and Browne 1977).

Differential rates can also be based on a two-step tariff, such as the IBRD has suggested for Kenya: a certain fee for the first 8 m^3/month for each household at a low price and a higher price for volumes above 8 m^3 (Idemalm 1978). Different prices should also be introduced in areas of different agricultural potential and there would be a small difference in price between treated or untreated (or as the current euphemism goes "high quality" and "low quality").

At this point, we would only like to mention the increased administrative problems a tariff system would have as a consequence. Not only because of the notoriously difficult revenue-collection practices but also because of new routines which such a system demands. Meters have to be installed, they have to be calibrated, checked at regular intervals, read, and bought from abroad at *ca.* U.S.$ 60 a piece which, for example, in Kenya in 1978 would amount to an estimated total price of *ca.* U.S.$ one million. The additional demands on the operation and administration of rural water supplies may be overcome in the long-term, but for the short-term they seem unrealistic.

(b) Pricing of irrigation water

There are three reasons for levying water charges on irrigation water: (a) to cover financial costs (cf. for example, Doppler 1976), (b) to counteract misuse such as overwatering and promote water conservation (Thornton 1975, NCA V 1976, Asopa 1977, Takase and Wickham 1976), and (c) to tax the relatively privileged section which is benefiting from water (Hyderabad 1978). A further reason voiced by Bokhari (1977) is that the water is the property of the state and has to be paid for. It would, however, seem that such measures have a limited power. Bottrall has suggested that charges are not important for water conservation in

new projects. Good water-management has to be learned. However, he suggests a positive correlation between the scarcity of water supplied to the farmer and the cost to him of using it (Bottrall 1978a). Uneconomic water charges are therefore never justified. Kinawy (1977) mentions a similar situation in Egypt: low fees do not prevent the unwise use of water.

If water rationing is the main objective, there are other methods than water levies which should be looked into, such as keeping channels at a lower level than the field so that water has to be lifted onto the field, to take pumps away for certain periods, or cut off the electric power, or some such measures.

Although most governments agree that at least a part of O and M cost should be recovered from beneficiaries, this goal is rarely achieved. There are many practical problems involved, such as metering and charging for irrigation water (Lazaro *et al.* 1977), underpaid collectors (Corey and Clyma 1975), education in the proper use of water (Bottrall 1978a).

Therefore, the choice between different kinds of charging becomes interesting. One can choose between volumetric charging, flat rates, indirect charging and direct charging of costs to beneficiaries.

In Bangladesh, the cost of installing tube-wells and low lift pumps is in the form of a rental charge or pumps are bought by farmers on hire-purchase. Cost recovery is between 30 and 75 per cent. Water charges are set at 3 per cent over the gross incremental benefit over the pre-project level, but because of this complicated assessment and independent policies followed by the Bangladesh Water Development Board and the Bangladesh Agricultural Development Corporation, "practically nothing is recovered from the beneficiaries" in the BWDB projects. Some farmers pay higher premiums, as there is a high demand for high-cost irrigation sources which indicates that there may be room for higher rates (Hussain 1978).

All the different types of charging are to be found in India, and the methods vary from state to state: fixed charges, indirect charges in the form of betterment levy or land revenue, volumetric charges in tube-well schemes. Recovery rates are good, but never cover O and M costs (Kathpalia 1978). In Indonesia, farmers pay an indirect charge in the form of increased land tax; otherwise water is free (Soekadaryanto 1978). In Malaysia, direct levies are taxed on the size of the land and the farmer also pays Islamic paddy production tithes, *zakat*, to the State Religious Affairs Department. Irrigation rate and *zakat* cover O and M (Abdullah 1978). No water charges are levied in Sri Lanka, but there is a Land Betterment Tax (Perera 1978). In Kenya, water rates on National Irrigation Board Schemes are charged to cover O and M, under the threat of eviction from the scheme for default (Gitonga 1978). Subsidized rates are usually paid in Nigerian irrigation schemes, according to holding (Popoola 1978).

Volumetric charging causes irrigation authority income to fluctuate and entails an increased administrative input, which in places has grown in complexity out of all proportion. Flat rates encourage overwatering and therefore necessitate central administrative measures such as rationing in time or space. Indirect water charges do not permit economically optimal methods of production: if there are charges against one type of crop, farmers may change to a "cheaper" crop (Doppler 1976). Charges against area cultivated or irrigated are usually very arbitrary and, as Bhuiyan (1977) has shown from Bangladesh, do not represent true pumping expenditure.

More important than the size of the levy is thus the way it is charged. There are many other ways which merit consideration such as "quasivolumetric" measuring of the time farmers receive water, either individually or in groups under a single outlet.

It is also important to make sure that the farmer really is a beneficiary of irrigation water and that there are mechanisms for waiving levies in case of unreliable water delivery or in case of crop failures.

(c) Sanitation charges

The economics of sanitation are, of course, as important as those of water supply. But as sewerage systems, unlike water systems, are financially non-remunerative, the installation of household excreta-systems has in most places been left entirely to the householder's discretion. The economics and the social benefits, however little we understand of the tenuous link between health and sanitation, must be considerable, as has been slowly recognized. Therefore, programmes for basic rural sanitary services have better chances of ready acceptance and implementation, if pursued as parts of total rural development involving several agencies and ministries. There is already a realization of the value of a multi-pronged approach in programme planning and implementation. But the truth is that we know very little about how to promote a successful rural latrine programme. It depends on the rural dweller earning more than a subsistence minimum and on "marketing" the idea of latrines, as funding has to come from local sources. Impressive task-force type programmes have been working for some time in Sri Lanka and Thailand (WHO 1977, Widstrand 1979).

The appropriate level of water charges, both in household supply systems and in irrigation, as well as the best methods of collecting these rates, form an important topic for future discussion and research, as does indeed the whole area of the financing and economics of rural sanitation systems.

(5) Flood preparedness

Although floods occur more or less regularly in all arid and semi-arid regions, the monsoon and typhoon areas of South East Asia are most severely struck by floods. In some parts of the region, flooding is a regular (seasonal) phenomenon, but, yet, when it occurs it occurs suddenly with enormous damage. For the ESCAP region the damage caused by floods has been estimated to some U.S.$ 3,000 million per year (ESCAP 1976). According to RAO (1975) there is still no method by which to predict the occurrence and magnitude of a flood well ahead of the season of heavy rains. This means that protective measures and the operation and administration of these measures become of utmost importance (Abbas 1973).

There are basically four types of measures that can be taken to prevent flood damages (ESCAP 1976; Rao 1975). The first and most widely used consists of different kinds of structural measures. Embankments and channel improvements may be constructed to reduce inundation; reservoirs and detention basins may be constructed to reduce the flood flow, as well as diversions which take the water away from the main course.

It is, of course, important that the structures are properly designed, for example, that embankments are constructed sufficiently far away from the main river channel. Otherwise, if built too near the river, the main effect will be an increased flood height.

Equally important to the construction itself are sound operation and maintenance of the structures. Embankments have to be protected against, and repaired after, the rise and fall of the flood flow which often causes heavy erosion. This erosion, in turn, causes loss of productive land, and, together with silting, reduced capacity of the river channels, which often leads to very costly dredging problems (Gupta 1977).

One general problem of flood preparedness is that during dry seasons or when floods are not to be expected the incentives for protective works may not be sufficiently strong. The political problems have been summed up by a leader in *The Statesman* (New Delhi, 19 Aug. 1978): "... Parliament's indignation is roused only when the waters are at their highest; demands and pledges alike being quietly shelved once the deluge has disappeared..."

But there are also problems involved in, for example, multipurpose reservoir operation. According to ESCAP (1976), conflicts are likely to appear on the need to conserve water for other purposes against the need to save storage space for flood control. Although a reservoir is designed for multipurpose use, including flood control, the high short-term economic value of water for irrigation or hydropower would be too strong an argument not to sacrifice some flood mitigation benefits in favour of increased supply benefits. An example is given by Mukherjee (1978) who, in describing the operation of a dam in West Bengal, India, states that the eagerness to generate more power made those responsible for the operation impound as much water as possible in the reservoir during the rains in May-June. When it then rained heavily during the monsoon, there was no way of reducing the river flow and consequently vast areas of West Bengal were flooded (cf. also *The Statesman*, New Delhi, 17 Sept. 1978).

The second measure is watershed management, or more specifically soil conservation, which serves the purpose of reducing both flood flow and erosion. Moreover, it is likely to provide additional economic output, if properly managed. Especially important is the afforestation in upstream areas. In fact, it is just the intensive deforestation during the last century which is claimed to be the most important reason for the large flood damage in South East Asia. Vohra (1978) advocates that the creation of embankments offers no solution at all to the real problem of floods, but merely creates the illusion of doing so. The only choice for India is to conserve the soil by putting the idle land to work and to get every acre of land to yield the very best it can, whether this is in the form of crops, trees or grasses.

The third measure to prevent flood damage is careful planning and development of flood-prone lands. This is, however, a difficult problem, as such lands are often the most productive and increasing demands for agricultural production makes it almost inevitable that settlement and development will continue to occur in these areas. Rao (1975) blames the increasing damage and loss of life and cattle from floods in India on the unregulated development of flood plains. Urbanization and industrial development in areas normally liable to floods have especially increased the damage sharply. On the other hand, some protective measures have been taken. For example, a large number of villages in the eastern districts of Uttar Pradesh which used to be inundated during floods have been moved to a higher level. This was regarded as a better method than construction of embankments, primarily because of drainage problems. The moving of the villages has first of all saved recurring costs of relief measurements, but has also enabled the farmers to stay near their land during flood times, which is regarded as an important social gain.

The fourth measure, finally, is of such non-structural types as flood forecasting and flood warning. As was mentioned earlier, long-term forecasts ahead of the monsoon and typhoon seasons are not possible with conventional methods. Therefore, the methods based on the "simple truth that water conditions and rainfall are dependent upon planetary influences" and advocated in an editorial of the important Indian monthly *The Astrological Magazine* may be as good as any:

> "Let not meteorologists arrogate to themselves all the wisdom of weather-forecasting. Let them take advantage of the astrological lore available in ancient books, combine it with their own studies and observations so that more reliable forecasts could be offered for the good of the people" (Raman 1978).

In New Delhi, on the River Yamuna, a two-day forecasting system has been developed which has been implemented also on the Ganges and other rivers. The system is operated during the monsoon season and gives forecasts every day for the following 48 hours.

The forecasting system is, of course, of no value, unless it is connected to a well-functioning warning system. The design of such a system is a delicate problem in itself. Warnings should not be released too early. They might then cause unnecessary preventive costs and also lead to disbelief among the population. On the other hand, they must not be released too late, in which case disastrous damage may occur.

Both these measures are, of course, also valueless, if there is no political will or administrative commitment to act, if there is no disaster relief system, or a planned flood-rescue system or other emergency measures.

All these measures to mitigate flood damage require highly committed administrative staff, as well as a sound organizational structure. In India, with her large number of rivers and where the problems are huge and complex, protective measures can be effectively implemented only by concentrated action with necessary coordinating agencies at the national level (Rao 1975). Until 1954, state governments were responsible for the flood control programmes. These uncoordinated efforts did not prove productive. Therefore, a Central Flood Control Board was created to lay down a national policy on flood control in the country and to provide guidelines for the State Flood Control Boards (Varma 1978). However, Rao (1975) claims that even this arrangement has not been found to be fully adequate. It was therefore considered desirable to conduct investigation, planning and implementation of flood-control works on a central level. After the devastating floods of 1975 a National Commission on Flood Control was set up. But, according to *The Indian Express* (1978), the creation of the Commission seems to have been an alibi for evading positive action. "The commission itself has remained in a state of suspended animation after the first chairman named for it was moved to a political office. Nobody has been appointed in his place."

In spite of all preventive efforts there is always a risk that flooding will occur. First of all, the watersheds may be such that sufficient flood-storage reservoirs are infeasible. This is largely the case in the flat Ganges basin. Second, if sites are available, it is not possible to design structures which cover all future flood events. The Yamuna flood of September 1978 is a good example. An evaluation made by the Central Water Commission estimated the event as one occurring once in a period of 500-800 years. The measuring point at the old railway bridge in Delhi was bypassed by twice as large a discharge as was ever recorded before (*The Times of India* 1978). The fact that there will always be a larger flow sometime in the future for which no protective work can be enough calls for a highly efficient rescue and relief organization. This should be prepared to provide hard stricken people with food, drinking water and medicine; and when action is needed it should be initiated immediately without being delayed by political disputes. Such situations as the 1978 flooding, which affected millions of people, show that cooperation is necessary between all actors, from the individual in charge of private and official organizations, through state governments with their limited resources, to the Central Government (*Amrita Bazar Patrika*, 1978).

MAINTENANCE

(1) Introduction

Maintenance is a repair and overhaul operation done periodically, to restore, repair and keep up water-supply systems for drinking water and irrigation. The main problems are here, as in so many other cases, problems of recurrent costs, problems of local administration, scarce personnel and a local population not very interested in such operations. More funds from donors are slowly coming into this area, but they are usually for training programmes for mechanics, lorries for regional workshops and one or two new machines. But there is nowhere a major input of thinking of maintenance problems in the planning of water supplies or irrigation.

We also know fairly well where and what the problems are. One such problem which we will illustrate concerns spare parts and the interesting fact that donors prefer to donate pumps and metals which are made according to their own standards. Much machinery is rendered useless because of the constant problems of fitting English, American, German and Swedish pieces together.

We would like to put forward one idea here, and that is that local people could probably be mobilized for the fairly short-term job of setting up a water supply system. Special engineering services could be provided as well as drilling rigs, etc. Such work is short-term and would be suitable for local initiative. Operation and maintenance, which today almost everywhere depends on the initiative of the local population, should be handled by government. This is a long-term job and if government is relieved of the construction problems much capacity and personnel could be mustered from the O and M job, plus the technical services necessary to help local people with construction.

(2) Spare Parts

The spare-part problem starts already with the choice of technology, whether equipment should be imported or manufactured locally. The general view is that locally manufactured equipment, above all spare parts, is much to be preferred. The continuous import of spare parts becomes expensive and causes long delays of maintenance works. The delays are, however, not always directly caused by the import as such, but by the very strict import rules imposed by the receiving countries. WHO (1977) as well as ECA (1977) conclude that because imports may be inevitable for some time, greater standardization of equipment among suppliers should be imposed, but the long-term strategy of each country should be to invest part of its foreign exchange in the promotion of local manufacturing of equipment and spare parts. This, of course, requires that technologies are chosen and designed so that the fabrication can be made within the country, i.e. they must be reliable, have reasonable costs, and should be maintainable by the local population (Salisbury 1978; Henry 1978).

But it is not enough only to manufacture spare parts in the country. Those parts must also reach the breakdown sites and be properly installed. That this is not always easy to obtain is shown, for example, by Matango and Mayerle (1971). Some of the water-supply schemes in Lushoto District in Tanzania had come to a complete halt, because the technical advice available could not serve every scheme at the time the service was needed. There was only one technician whose visits were constrained by lack of transport to reach the schemes and to deliver the materials, and by the necessity to spend two or three days with one scheme before entrusting the work to the local mechanics. Also, materials could not reach the schemes in time, because they had to be purchased in Tanga or Dar es Salaam. Heijnen and Conyers (1971) proposed some hypotheses from a study in East Africa. Pumps are frequently out of order and repairs take a long time due to a shortage of technically qualified personnel and to a lack of finance.

The conclusions to be drawn from the experiences above are that maintenance should be decentralized, but provided with financial funds, e.g. maintenance must be properly regarded as an important phase already at the planning stage. Local participation of skilled and motivated people seems to be necessary and has proven to be fruitful. There are good experiences from Latin America and from Malawi, where promotion and training have been integrated with rural water-supply projects (Salisbury, 1978; Schultzberg, 1978). Some of the more important problems of maintenance and possible approaches are given by de Ridder (1977) in a description of the shallow-well programme in Tanzania: "The maintenance and repair of the wells ought to be organized by the local authorities. But the heavy financial implications of such work means that it ranks low on the list of priorities. The suggestion has, therefore, been made that minor repair and maintenance work be left to the villagers, who should appoint a well attendant for this purpose. It is obvious that whatever a village can do for itself should not be done by others, but in Tanzania the limit of self-help is quickly reached. In the harsh environment in which most of the people live, their main concern is simply how to survive: much time is spent on cultivating the fields for daily subsistence and on fetching wood for cooking and water for drinking, all on foot. Nevertheless, somehow or other, the people must be taught how to use their wells. Unless this is done and some form of maintenance is organized, there is little hope for a long lifetime for the wells provided by the project".

A prime reason for repair needs, apart from wear and tear, is vandalism, which occurs in both construction and operation phases of water-supply projects. Experiences from East Africa show that taps, valves and pipes are often stolen during construction. The reason behind this may be lack of knowledge ("Why not use the equipment for some other good purpose? There is, anyway, no water coming out the installation.") or frustration ("Now I have been waiting several years for a water supply. Here it is, but there is no water.").

The vandalism during operation may be due to the same factors. Metal parts, such as taps, valves and fences are often stolen to be used elsewhere and/or sold in the market. Salisbury (1978) reports, for example, that brass parts are often stolen from pumps in India, because they can be used for pots and pans. To avoid this problem, pumps were instead being made of cast iron. But then it turned out that local blacksmiths were not at all acquainted with this material. As a result about 80 per cent of the 50,000 cast-iron wells in drought-prone, hard rock areas had broken down and were thus not producing any water (Henry 1978).

(3) Land Maintenance

Traditionally, and for a variety of reasons, irrigation development has taken place principally on the most productive agricultural lands. From earliest times, though, carelessness or ignorance of requirements in irrigation management has led to such decline in productivity that settlements have been abandoned. In recent years, however, very expensive rehabilitation measures have been considered necessary (ESCAP 1976).

A basic cause of the decline in soil productivity is waterlogging which occurs when the soil pores within the root zones of plants are saturated with moisture. This leads to two effects adverse to production, namely a cut-off of the normal air circulation in the root zone and high salination, which sometimes may prove toxic to the plants. Thus, drainage of wet lands and especially irrigated land is mandatory, above all in flat alluvial plains. Chaturvedi (1976) suggests that some river-valley civilizations were destroyed not by lack of water but by overirrigation. The lack of drainage seems to be due to the view that drainage is an unproductive activity giving no benefits. This is wrong. Irrigation must be combined with drainage and the excess productivity must be credited to both

activities, as irrigation alone provides only short-term benefits and high costs in the long run (Kovda 1979).

According to Chaturvedi (1976) again, only a very small part of the irrigated land in India can be said to be properly drained. Rao (1975) mentions only the Kinshasa and Godavari deltas, while about one million hectares in the Punjab and Haryana are severely affected by waterlogging.

The situation in Africa is similar. In Egypt, for example, the present agricultural development is directed towards reclamation of new land. However, two-thirds of this new land is considered not to have been made fully productive. The reason is overirrigation which results from water being free of charge. The absence of drainage leads to a considerable rise in groundwater level causing severe salinity. The agricultural development seems therefore to have fallen into a backwater. Development funds are put into projects which malfunction for the same reason that old lands are abandoned. It seems to be more appropriate to rehabilitate, i.e. drain old lands before going into reclamation of new lands. ECA (1977) concludes along the same lines that there is a need

(a) to evaluate the most suitable soil and water conservation methods to suit the local economic, social and environmental conditions;

(b) to re-examine population settlements within the water catchment areas;

(c) to educate farmers on the benefits of soil and water conservation measures;

(d) to reinforce legislation on soil and water conservation.

SIZE

(1) The Extent of the Problem

The sheer size of the problems discussed in this volume is almost beyond comprehension. Assessments of the global situation have been made by the UN Habitat and Water conferences. They are the only figures available although some extrapolations have been made. Thus in 1975:

- 1,100 million people or 85 per cent of the rural population of the world did not have reasonable access to a *safe water supply*;
- 23 per cent of the urban population were in the same predicament;
- 1,100 million or 85 per cent in rural areas did not have any sanitary facilities;
- 150 million or 25 per cent in urban areas were not served by any sanitary facilities
(UNICEF 1979).

Man uses 2800 km^3 of water per year for irrigation of 223 million hectares. Of this area 92 million hectares are in developing countries. For the next 15 years rehabilitation work on 42 million hectares has been suggested by the FAO. To meet increased food demands, FAO has suggested new systems to the extent of 23 million hectares. Furthermore, drainage is urgently necessary both on irrigated areas and areas under rain-fed crops, altogether 80 million hectares, or three times the irrigated area of Pakistan (Gustafsson 1977a, ECOSOC 1976).

TABLE 3:5

IRRIGATION IMPROVEMENT TARGETS 1975-1990
(AREAS IN 1,000 HA. COSTS IN U.S.$ MILLIONS)

Region	1975 existing irrigation area	Minor improvement area	Cost	Major improvement area	Cost	TOTALS Area	TOTALS Cost
Africa	2,610	522	209	261	235	783	444
Latin America	11,749	2,349	566	2,349	1,540	4,698	2,106
Near East	17,105	6,368	3,184	3,421	3,079	9,789	6,263
Asia	60,522	17,614	5,284	12,104	8,472	29,718	13,756
TOTAL	91,986	26,853	9,243	18,135	13,326	44,988	22,569

Source: ECOSOC 1976.

A comment on the statistics is necessary. As we have discussed at other places in this volume "aggregism" is rampant in world statistics. By aggregism we mean the attempt to avoid small-scale studies or data from small-scale situations by confining analysis and policy to the manipulation of big aggregates (Widstrand 1970). What do such statistics really show? Size of problem? Yes, but what problem? They have been collected officially, and have the inherent bias of national pride or national masochism, like all UN statistics. They may not represent situations as they are locally. Even if 19 per cent of the rural population in South East Asia have "reasonable access to safe and adequate water" according to the statistics, it is probably not 19 per cent in each country or each village. Maybe quite large portions are unrecorded? Furthermore, it really does not tell you anything of what should be done about the problem or what is being done about the problem at the local level. Exploration of trends in the past may give totally wrong answers because development, whatever is meant by that, is not a steady process but rather goes in leaps and jumps. A new busline through a village could mean more than many years of government integrated rural development, a new road can bring new disease, tax collectors and the modern world, all of which in one way or the other affect development. Gilbert White has recently written about water-supply statistics and suggested that one should know more about the following parameters:

(1) spatial configurations of the population,
(2) the proportion of population in urban squatter settlements involved in self-help projects,
(3) the character of water supply in urban slums in relation to provision for water-borne waste, and
(4) the proportion of rural population involved in some organized form of self-help community development.

On the government side it would be desirable to explore:

(5) the extent to which there is involvement of users in choice of water-supply service level, technology, and management policy,
(6) the investment which the national government is prepared to make for improvements in water supply on a *per capita* basis (White 1977).

One dimension of this type of discussion concerns the size of the costs involved and the manpower needed. The UN Water Conference assessed the cost and manpower requirements for some of the goals discussed during the conference:

TABLE 3:6

Goal and scale	Cost in million $	Manpower requirements: Professionals	Technicians extension workers	Observers skilled labour
(1) Safe water for all 1990*				
Additional population to be supplied:				
water supply - 2,200 millions sanitation - 2,300 millions	133,000	(estimate missing)		
(2) Water for increased food production*				
new irrig. 22.2 million ha. improved irrig. 45.0 " " drainage 78.0 " "	98,000	5,540	50,760	174,900
(3) Water assessment by 2000*				
surface water networks to meet standards				
groundwater to be investigated in 51 million km^2	15,500	1,040	4,700	42,000
TOTAL	246,500	6,580†	55,460†	216,900

*Except centrally-planned Asia.

†Excluding manpower needed for community water supply.

Source: E/CONF. 70/11, 13 and 14.

Another aspect on size is the amount of human misery and rootlessness which has been the result of the construction of large dams. The construction of dams in Africa has relocated enormous numbers of people: Kariba Dam (Zambesi River) 56,000; Volta Dam (Volta River, Ghana) 70,000; Kainji Dam (River Niger, Nigeria) 41,000; Kossou Dam (Bandama River, Ivory Coast) 80,000; Aswan Dam (River Nile, Egypt and Sudan) 150,000 (Warren and Rubin 1969, Chambers 1970, Dafalla 1975).

A third aspect of size has to do with changing needs.

(2) Changing Needs

(a) Water needs change over time

In most primitive societies, water needs are mainly biological. During subsequent phases of social and economic development, materially-based needs are added to the biological ones, and gradually take on the character of real needs. In modern society, psychologically-based needs may turn up, often as a reaction against damages caused by too short-sighted exploitation of natural resources during the period of industrialization.

The successively broadening array and increasing number of water needs during the course of societal development might be thought of in terms of different generations of water demands. The first generation then has to do mainly with the biological needs for survival. It includes the amount of water needed for a hygienic standard high enough to allow an acceptable state of public health, but also a certain amount of water necessary to grow the food necessary to secure a certain minimum level of nutrition for the population (including basic aquaculture). The second generation of demands would then include the water uses for securing the agricultural surplus and the industrial development necessary to create a basis for export. In this generation, we would then include water-power production, water supply of industry, irrigation water for large-scale agricultural production, water for urban development, including different kinds of urban services (hospitals, street cleaning, fountain waters, etc.). The third generation of demands, finally, covers recreational uses, leisure fishing, tourism, nature and wild-life conservation, preservation of water landscapes, etc. In modern societies, this generation, in response to a far-reaching environmental degradation due to second generation activities, in fact may take the form of non-exploitation of water resources.

(b) *Per capita* water needs

Water needs are often presented on a *per capita* basis. In primitive societies where household water is carried by women and children, the need may remain as low as 5-25 l./p.d. (litres per person per day), depending on the distance to the water source and on different cultural factors and water-use patterns. Standpipes in the vicinity of the home makes water more easily available, increasing the *per capita* amount. When later individual house connections are realized there may be a 3-4 fold increase in the *per capita* use (Feachem *et al.* 1978). Figure 3:1 shows 20 l./p.d. as a typical value for standpost delivery, whereas 100 l./p.d. is attained where there is a high proportion of house connections (Schultzberg 1978).

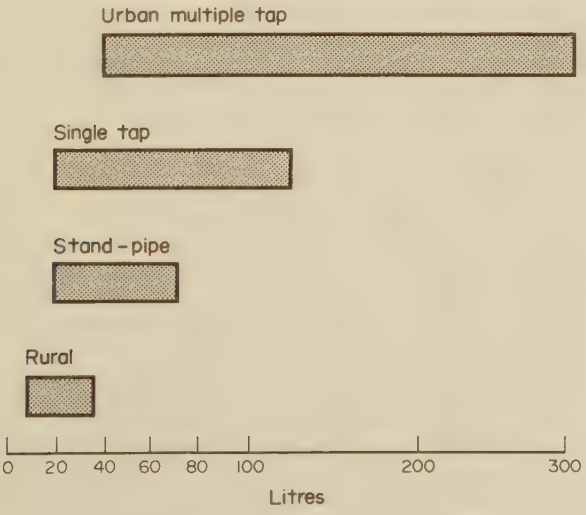


Fig. 3.1. Range of daily domestic water use *per capita*.
Source: UN 1977

When industry develops, the amount needed increases. In regions with water-surplus conditions, some branches of industry have developed technologies with high water demands. At present, water-saving technology is, however, being developed in many places in order to reduce the dependence of industrial development on the availability of large amounts of good quality water, which is often difficult to satisfy under water-scarce conditions, especially in densely populated areas. The amounts of water needed for irrigation in such areas may indeed be very large. In India, for example, agricultural water-needs account for 94 per cent of the total withdrawal uses (Chaturvedi 1976).

In consequence, the *per capita* water needs increase substantially when passing from the first to the second generation. When passing on to the third generation, the demand is more quality- than quantity-oriented, and development of higher water-use efficiency may even reduce the quantitative needs (Fig. 3:2). All the three generations could be seen as consisting of a series of substeps taken to develop successively a decent water supply in the whole country. Each generation may take many decades, or even centuries, to fulfil.

In most developing countries, there is at the same time a substantial increase of population, implying that planning has to be performed with a new unborn or "shadow" population in mind. Future-oriented scientists in India use the expression the "Second India". Due to the continuous increase in the population, the absolute water need increases successively, even if there is no increase in the standard of living. This "automatic" increase of water needs has evidently to be met to keep the standard of living already attained.

(c) Changing needs have to be taken into account in planning

Successively increasing water needs in water-scarce areas may rapidly turn into conflicts. Prospective planning is a measure to avoid such conflicts. Planning has to be done in such a way that changes are anticipated not only in human needs but also in social values, policies, institutions and technology.

The water-scarcity conditions of many developing countries in tropical regions makes water-resources planning a necessary measure at a much earlier stage of development than in countries with water-surplus conditions, where there are ample amounts of water available to satisfy increasing demands for a long interval of time, even in a piecemeal manner without regular planning.

There are also clear differences in the way in which the two groups of countries advance from one generation of water needs to the next. The countries already industrialized have followed a rather slow course and it took several centuries to pass the stages of the two first generations. In less developed countries the "pathway" will hopefully be more rapid, but at the same time more complicated. In the first place, knowledge is now available on the environmental mistakes made by the industrialized countries, and could therefore be counteracted when planning for the second generation of water needs. Secondly, the resource situation in the tropical zone differs substantially from that in industrialized countries. This makes it necessary to embark at an early stage on multipurpose water projects, including certain second-generation measures when solving the problems of the first-generation needs. At the same time, the conventional single-means approach, typical for the developing phase of the industrialized countries, could be avoided in favour of a multiple-means approach. Up till now progress for society in industrialized countries has been founded on making an increasing amount of water available. There are, however, other ways of meeting broadening water needs, not only technical means (in order to make increasing amounts of water available), but also control of needs by creating different incentives of a legislative or economic nature (UN 1977c).

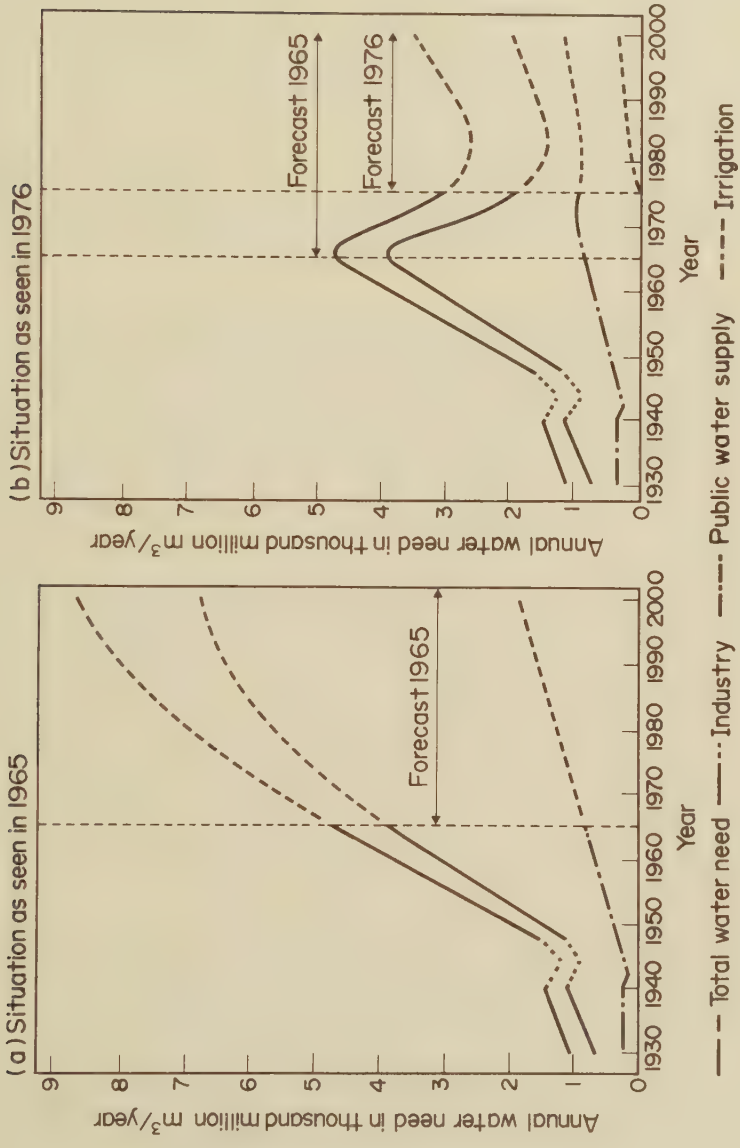


Fig. 3.2. Development of water demand in Sweden; actual and according to forecasts in 1965 and in 1976. Source: Falkenmark 1977b, AMB 10 1977

(3) Large vs. small Projects

Some water projects are very big. In the water field, gigantism or elephantiasis has celebrated triumphs almost unparallelled elsewhere in rural development. Projects like the Tarbela Dam in Pakistan, the Aswan Dam in Egypt and the Jonglei project in the Sudan are very large projects. Such projects depend on sophisticated technology and foreign knowhow and capital. Projects like the damming of the Rufiji River in Stiegler's Gorge in Tanzania, financed with relatively short-term loans will run up interest and loan-serving expenses which will stress the Tanzanian economy enormously. The settling of people from the Kenyan Central Province in irrigation settlements on the lower Tana River at a price calculated at $25,000 per family is another type of large-scale and costly water project.

Such concentration of investments to a limited region may result in reductions elsewhere. Large-scale projects also require foreign aid, followed by expatriate consultants. "The terms of reference and the time scale associated with the use of external consultants are such that serious problems with the basic premises for the project can be expected" (Levine and Wickham 1977).

There is, of course, some economy of scale in such projects. Larger reservoir capacities give less fluctuation in water delivery (or should at least in principle do so). The settlements made possible by the Aswan dam are also large. But size is deceptive. There are no problems in selling a large-scale project to a government: the arguments of "nothing-but-the-best-will-do", and "economic success makes welfare possible, not the other way around" are always there. Those of the authors of this volume who are not engineers have a suspicion that there is something in the engineering training that produces an almost unconscious pre-selection preference for the large-scale, for the technically complicated and for the expensive.

What has emerged over the years is that maybe the next-best would have done better and that welfare is further away than ever as economic success did not materialize. Size is deceptive. The Tarbela dam, built at a cost of over U.S.$ one billion, is too small. It can hold only one seventh of the annual flow of the Indus. For comparison, Lake Mead on the Colorado has a capacity of twice the annual flow (Eckholm 1976). This makes the Tarbela uneconomic and does not generate any assured water-flow. The Aswan dam was obviously planned without taking into consideration the special features of the Nile river and its behaviour over the year. The agricultural capacity which was made productive thanks to the dam has already been pre-empted due to the population increase. Several ecological problems have also been created, in the delta and elsewhere. The dam has not, however, contributed to the increase in schistosomiasis (Miller *et al.* 1978).

The hydroelectric power dams in the Seven Forks area of the Tana in Kenya have an estimated life span of ten years, due to accumulation of silt, as there seems to be no possible way of preventing large-scale deforestation of the upper part of the watershed. The coordination of the planning has not been optimal, to say the least. This "it-is-not-my-table" philosophy is not unusual (*The Weekly Review*, Kenya 27 July 1979; Ongyweny 1977). A sequence of events in Afghanistan has been analysed by Michel (1972). The Helmand project was enlarged, due mainly to factors of national and personal prestige and usual considerations of professional optimism. This decision was mainly due to the fact that the contractor, American in this case, set a minimum level under which it would not pay to operate in Afghanistan. A further storage dam was considered necessary to provide water for the new area and not to detract the water available for the flood plains further down. This extension destroyed the project, as the canal from the dam, the Boghra canal, made the water table rise 16 feet in a couple of years. That this problem would arise was well known to decision-makers and to the contractor, but still the project was enlarged and implemented in defiance of reality (Michel 1959).

Vohra says: "Excessive preoccupation with gigantic irrigation projects and the pre-emption of large financial resources for them ... led to an almost criminal neglect of groundwater development as well as of small soil and water conservation works" (Vohra 1975). Yet investments in both these fields have, as far as we know, yielded much better results.

Large projects are often also new projects. With new projects you bring in new people, which is a positive thing. It also seems that it has been much easier to get money for new projects than for the rehabilitation of old ones.

Rehabilitation is also a large problem and over recent years, since the World Food Conference in Rome 1974 it has become more and more interesting to donors. There are now funds available for rehabilitation programmes. Rehabilitation can mean two things, either desilting and repair of water-control structures or the repair and expansion of the capacity of water-storage and water-conveyance systems (Lazaro *et al.* 1977). Rehabilitation can be considered a deferred maintenance, since well maintained installations do not need periodic renovation (Levine and Wickham 1977).

Equitable distribution cannot be accomplished without an improved distribution system. The Subsidi Desa programme in Indonesia has shown that rehabilitation and improvement of existing structures is an effective way of mobilising rural people (Hafid and Hayami n.d.). The problems of relocation are also small. Water-course improvement along with improved field-irrigation practices could do more to increase food production than many "other water management programs including the building of any number of Tarbela dams" (Clyma and Corey 1975).

We are, however, faced with one problem and that is that we know much more about the failures and why large projects have not performed according to expectations than we know about the performance of small-scale water programmes. There is a slowly increasing literature on small-scale irrigation, mainly from South East Asia, but there is precious little about the performance of small-scale rural water and sanitation programmes.

CHAPTER 4

Policy and Planning

INTRODUCTION

In Chapter 3, we discussed at some length different aspects of water management and the man-management necessary to achieve the full benefit of water projects. We may expect that the third development decade will place great emphasis on water development and that huge resources — intellectual, manpower as well as financial — will have to be put into this field. A sound starting point for future water development would be to strive at avoiding, as far as possible, the repetition of past mistakes.

In his paper on planning in Volume 1, James concluded that basic planning principles are equally applicable, irrespective of whether the country is developed or developing (James 1978). For several reasons, however, the application, in terms of standards and procedures, is different. Differences in the general level of development imply that different emphases are placed on different societal sectors and on different generations of water uses.

Differences in climatic, hydrological, geological, demographic and cultural conditions also create different constraints on the planning process.

The chapter starts with a short discussion of ideal versus actual, single purpose versus multipurpose and sectoral versus comprehensive planning. We then go on to discuss the planning process, the group of planners and their role in clarification of goals and objectives, and some main differences between developed and developing countries. The chapter ends with a discussion on environmental concern.

The planning procedure as well as aspects of planning in general are well documented in scientific literature (Lichfield *et al.* 1975). However, in spite of the vast literature on these topics there are still very big gaps in the understanding of the planning process as well as related problems, including aspects of decision-making, the evaluation process, citizens' participation, the response of institutional organizations to suggested changes in directives, etc.

When talking about the planning process in general, we are also mostly referring to some kind of ideal planning. We are therefore faced with the question of how close we may approach reality by an actual planning process. There is, of course, no general answer to such a question, because the efficiency of a proposed plan must certainly depend on the character and complexity of the goals and the problems to be studied, as well as availability of fundamental data and kind of information

that can be transferred between various interested parties. We shall return to such problems when discussing the planning process itself.

Another point of importance to dwell on is the important difference between project planning and comprehensive planning. Closely related thereto is the question about sectoral planning and, for instance, regional planning.

Project planning may be for a single purpose or a multipurpose project. There is already a vast amount of literature on how to solve the multipurpose project by systems analysis (Biswas 1976, Haimes 1977). The choice between a single purpose and multipurpose project is closely related to the development policy that may affect the planning process itself. Thus in some cases the single-purpose approach may be successful. This certainly happens to be the case where water is to be used only for one purpose, or in cases where water resources are available in virtually unlimited quantities (Degen 1976). However, in most cases, we are in fact confronted with the multipurpose water-resources project which means that several purposes must be satisfied jointly. Such multipurpose projects may be thought of as reflecting different goals and objectives, in themselves competing and conflicting.

The inherent difficulty in solving such a multipurpose project lies in the fact that we do not have any mathematical optimization methods by which a multi-goal project will be uniquely solved, as illustrated by, among others, Rohde and Rouvé (1977). The characteristic feature of multipurpose projects as a competing-conflicting problem between, say, a simultaneous demand from industry and agriculture, makes it almost impossible in practice to adequately meet these demands. What happens is that we have to make compromises and as a consequence thereof we cannot guarantee the same degree of perfection in our calculations. Strict formal solutions are not to be found. More often, then, a series of approximate approaches and solutions will appear in the planning context that are sometimes controversial and complicated. Such situations are extensively dealt with in the literature (Bishop *et al.* 1976).

Another problem to be considered briefly in this introduction is the question of sectoral planning versus a total, comprehensive planning. If the sector in mind is the water sector, one may be faced with the fundamental question of how its development will contribute to the general development of, for instance, a region. What, then, will be the sectoral planning goals in relation to the planning goals in general for the region? One way of answering this question in a broad manner is to stress the fact that planning is only the instrument by which some idea of the future development of a region or a sector could be achieved.

SOME GENERAL ASPECTS OF THE PLANNING PROCESS

(1) The Planning Concept

Let us start this part with considerations about the concept of planning. Fundamentally, planning involves making rational choices among feasible courses of investment and other development possibilities on the basis of social and economic considerations. Moreover, planning for social and economic development aims at the best utilization of human and natural resources to meet popular demands for an improved level of living. Planning is, of course, closely related to development and the objectives of development may be seen as to make the greatest possible contribution to national welfare. However, national welfare is a complex concept that has many dimensions — social, personal, economic, as well as cultural.

These various facts must be taken into account when dealing with planning (ECAFE 1972). There are some commonly accepted notions as regards planning which might be expressed as follows: planning makes a development effort effective; planning can keep development efforts orderly, manageable and controllable, yielding faster results, better allocation of resources; and further, it can help to cope better with changing conditions.

Although there may be a short and concise definition of what is meant by planning, it is perhaps more instructive to elaborate on the theme a little more. Thus, planning has been interpreted as assessing the future and making provision for it, or anticipating what might happen in the future, and finally being prepared.

The future aspect of planning in a societal framework is a very important feature. Moreover, planning has been looked upon as a selection of objectives and a course of action to attain them. Then, planning may be incorporated in decision-making as well as problem solving, and finally in the case of resources development, in matching needs and resources.

The ECAFE publication emphasizes seven attributes of planning, which are quoted below in a revised form:

(a) Planning is concerned with the future. Moreover, planning is for the future, not for the present situation. It is done in advance or ahead of possible events or happenings.

(b) It is almost self-evident that planning invariably involves making present decisions. In fact, planning not only focuses on what has to be done in the future, but on what we have to do now in order to achieve certain things in a fairly unpredictable future.

(c) Planning involves predictions, forecasts and projections. Since present decisions will influence the shape of the future, effective decisions must be guided by adequate understanding of the future and its relationship to the present.

(d) Planning has to produce plans for development, implementation and management. The results of planning are identified as plans which are also the tangible results of the planning process.

(e) Planning must be a continuous process, a ceaseless cycle of decision-making, modification and/or revision. Planning is a basic management function. What has been said about planning as a necessarily continuous process depends on the fact that each decision now, to ensure the fulfilment of development desires, may give rise to secondary and higher-order effects, the consequences of which have always to be considered.

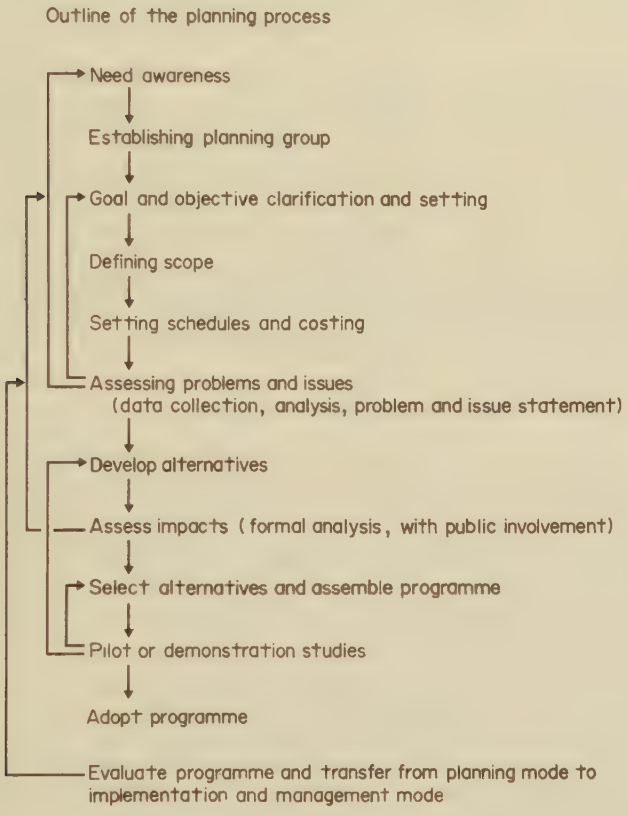
(f) Comprehensive planning is an interdisciplinary exercise. Many areas of knowledge are required. Water-resources planning, in particular, demands an appropriate blend of many fields of expertise and skill.

(g) Finally, planning involves risks and uncertainties and should possess flexibility.

(2) The Planning Process

(a) Need awareness

Figure 4:1 illustrates only one of many possible ways of putting together a series of factors that have to be considered in a logical order within the planning process.



Note: Feedback may occur from any step to a previous step. Similarly, feedforward may sometimes occur, skipping one or more intermediate steps.

Fig. 4.1. Outline of the planning process.

In this the planning activity starts with requirements such as a multipurpose scheme aiming at providing water for domestic, industrial, agricultural and hydroelectric power generation. Not only adequate quantities of water necessary for each specific purpose must be available, but equally important is the quality of water. For instance, a certain quality of water may perhaps be used for irrigation but is impossible for use in certain industrial processes, and vice versa. So quality and quantity of water are closely interrelated and the important issue is that both have to be considered simultaneously in all water-resources development projects. In fact, we may point out that quantity of water, without reference to quality, or vice versa, are rather meaningless terms for planning as well as management purposes.

The need of multipurpose projects has been taken as an example. Obviously, the attainment of socio-economic development objectives — as stated earlier — depends largely on sufficient quantities (and quality) for industrial and agricultural purposes. If combined with a competing demand of water for domestic purposes, we obtain a multipurpose and multiobjective project. As there is a trend of increasing demand from different users, there will be a corresponding need to regulate the water demand by well-conceived programmes and projects. The consequences of aiming at providing more water must also be recognized. Thus, intended programmes have to cover a wide range of activities ranging from the construction of physical and institutional infrastructures for the development, conservation, and distribution of water, to the provision of education and training for developing the skills necessary for using the resources efficiently.

(b) Establishment of a planning group

The next step to consider in our planning scheme is the establishment of a planning group — by no means an easy task. In an agricultural project — which *per se* may be a single purpose task — at least five professions ought to be involved (Shenoi 1975). The list consists of a planning economist to ensure perspective balance and consistency, an agricultural expert to propose feasible programmes, field administrators to ensure feasibility of the proposed policy framework, farmers, and political leadership to agree and commit themselves to the objectives and resource allocation suggested.

It goes perhaps without saying that a planning group of this size involves considerable administrative problems. The arduous tasks of data collection, preparation of the plan frame and the planning organization, etc. rest with this group. Such planning groups may be set up at different levels — national, regional, or local. The understanding and dealing with the political process is especially salient in countries where many projects originate at the local level and thus must progress through successively higher levels of approval, a fact that has been strongly emphasized by Howe (1976) in a survey of country organizational structures, represented by agencies and their tasks. He clearly demonstrates that a variety of organizations and water-planning responsibilities exist.

As one example, we may mention the United Republic of Tanzania, which generally is characterized as having a coordinated-decentralized organization. In Tanzania, *the Ministry of Water Development, Energy and Minerals* is responsible for water policy, and delegates tasks as follows:

Planning division: global water planning and interministerial liaison

Project preparation division:
- collection and analysis of data to be used in project design, evaluation and construction
- design of projects, including cost estimates and specifications

Construction and maintenance division:
- construction of projects
- operation and maintenance of projects

Manpower development and training division.

On the regional level, there exist the following organizations:

Office of the regional water engineer:
- design and execution of rural water supply programme
- coordination with regional development director

Regional water advisory board:
- issuance of water rights
- authority over structures and pollution

Special basin development authorities.

Finally, *on the local level,* we have

Village water committees:
- ensure participation of villages in all stages of project formulation and especially in operation and maintenance.

We shall return to the institutional arrangements for water management and planning when discussing consequences of the rigidity of such institutions in implementing developed alternatives.

(c) Clarification of goals and objectives

Primary goals may be defined in a very broad sense in order to cover the whole range of problems that need to be reformulated, initially by goals and later on by more precise objectives. Such broad terms set by the Government may be expressed as economic development, social progress, interregional balance, etc. Such broad objectives are accepted as fundamental goals in most countries where comprehensive water planning is actually put into practice (Armstrong 1972).

Figure 4:2 illustrates how broad goals may be subdivided into objectives of lower order (Bishop 1975). Such objectives may be achieved by a variety of means, such as intensification of agriculture, establishment of industries, promotion of tourism, growth of cities, modernization of rural areas, etc. However, broad objectives are often of no practical use because of their very general contents (Widstrand 1974).

"Improvement of the quality of rural life" is one way of characterizing social progress. The objective is too imprecise in this form, but it can be broken down into objectives that are more manageable characteristic factors, so-called indicators. In this respect we note that according to Vlachos and Hendricks (1977) there is a logical connection between goals, objectives, criteria, indicator categories and specific (measurable) indicators.

In order to see how the concept of specific indicators may be reached through this logical series, we have borrowed the terminology of goal disaggregation used by Vlachos and Hendricks (1977). The objective to be studied is the concept "recreational opportunity", a goal that, in fact, is presented in a rather broad manner. As illustrated by Fig. 4:3, objectives of this goal may be "stream-fishing" and "boating" etc. The figure shows how a consecutive breaking down of the components eventually ends up in three specific indicators, "temperature", "dissolved oxygen" and "toxic substances". These three indicators ultimately indicate decisive components of the broad goal "recreational opportunity".

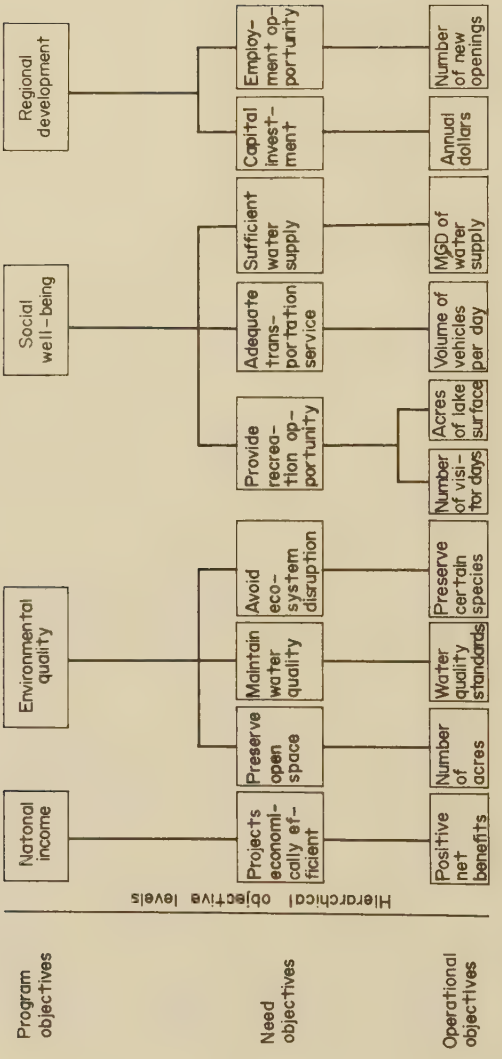


Fig. 4.2. Hierarchical levels of objectives according to Bishop (1975).

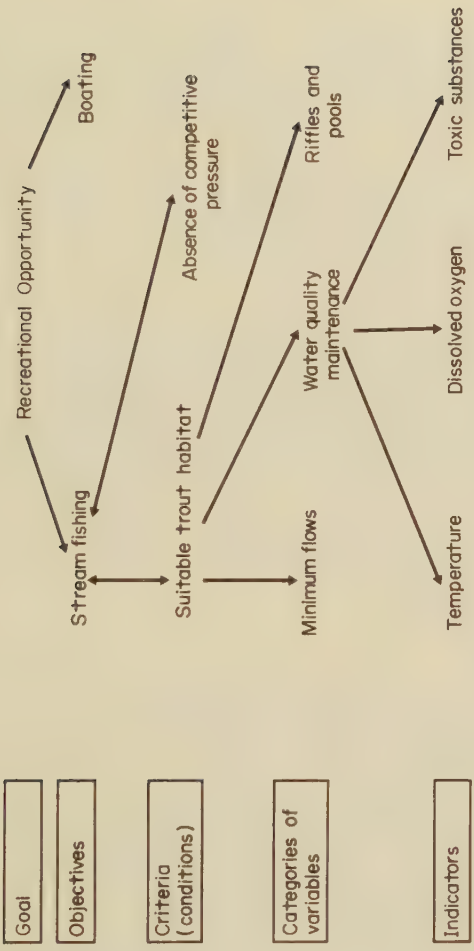


Fig. 4.3. Examples of a goal disaggregation process.

The use of indicators has been discussed intensely during the last decade. As we know, economic-statistic indicators have been widely used for a long time as a means of recording characteristics of economic development. Today there is increasing interest in the use of such indicators by which we might possibly be able to reveal characteristic features of society. The use of socio-economic indicators in this case is twofold: basically, to characterize fundamental patterns of the society, and secondly, possibly to affect society through imposing changes in these fundamental units that indicators are supposed to be (see, for instance, Land 1975; UNESCO 1974; UNESCO 1977).

Among sociologists and others, the use of socio-economic indicators has been very much under debate. However, when trying to delineate what is generally called the "social system" (Todero, 1977), i.e. roughly speaking the independent relationship between so-called economic and non-economic factors, socio-economic indicators may be of some use. As has been pointed out, the latter include attitudes towards "life, work and authority, public and private bureaucratic and administrative structures, patterns of kinship and religion, culture traditions, systems of land tenure, the authority and integrity of government agencies, the degree of popular participation in development decisions and activities, and the flexibility or rigidity of economic and social classes".

The problem of establishing goals and objectives is, of course, a very difficult task. One important thing to have in mind is that the actual role played by the planning group in the policy-making and goal-setting process varies from country to country. In many developing countries, considerable reliance is placed on planners not only for recommendation of solutions to problems, but also for identification of goals and active participation in the final decision concerning the action to be taken. Doubtless, there is considerable merit in having the planning function closely linked to the policy-making function, but it is possible that in such instances the goals reflect agency traditions and expatriate professional thinking.

To what extent does a plan truly reflect problems and — let us say — new social values? Let us try to summarize this as follows (ECOSOC, 1976):

(a) Do the goals reflect accurately current social values?

(b) Are the problems identified by the planners the same as those perceived by the public or other agencies?

(c) Does the range or choice embrace alternatives beyond those which have been used in the past by the agency involved?

(d) Does the weight attached by the planners to particular criteria for evaluation accurately reflect public preferences?

(e) Is there evidence to suggest that the recommended policy has been successful in the past, and whether it will have ecologically disastrous or other undesirable side-effects?

Where such questions can be answered positively, it is likely that the administrative framework has been flexible enough to respond to the new challenges of water-resources planning. Where there is some doubt, further adjustments may be needed.

PLANNING DIFFERENCES AND SIMILARITIES BETWEEN INDUSTRIALIZED AND DEVELOPING COUNTRIES

The water management and planning in the developing countries differ from those in developed countries on points which are quite fundamental.

Thus, in developed countries, individuals and institutions apparently readily accept new production methods, for instance, irrigation techniques. The reason for this rapid reaction can be explained by existing communications networks and the net of institutions already established.

Furthermore we must also understand that the main objectives of most developing countries have to be defined according to an integrated and intersectoral approach. This is quite in contrast to the situation in developed countries, which have been able to determine their goals and objectives project by project or alternatively sector by sector.

Lastly, it remains to mention that management capacity and skilled manpower resources are generally scarce in developing countries. This is perhaps one of the most important issues. Taken together, all these differences are significant, leading to the conclusion that the technology and methods of developed countries are not directly transferable.

However, there are also fundamental similarities, as, for instance, in the forecasting process. In each type of country, the immense difficulty in forecasting future events, even in the short term, and the need to leave room for innovation, calls for very flexible planning. We may recognize the importance of this attitude, especially when bearing in mind the time horizons and the size of the investment required for, say, hydraulic works such as dams, canals, water-treatment plants etc. that can hardly be completed quickly. It is equally important to stress that many water-using installations (irrigation systems, factories, urban networks, electric power stations etc.) have a considerable lifespan, which again means a strict adherence to long-term plans once they have been adopted.

MASTER WATER PLANS

A National Master Water-Plan exists or is being prepared in many countries. Its main objective is to ensure effective coordination of water-resources planning with other development-planning activities of the national development plan. A master water-plan is conditioned by four factors: (1) the large-scale water-related investments, (2) the irreversible and mutually exclusive nature of many development options for water-related investments, (3) the necessity to consider options using multiple criteria, including financial, economic, social, health and legal, as well as engineering and political criteria, and (4) the urgency of establishing feasible water-development options from which rational choices can be made. In the work on the master plan in Kenya, the first phase consisted of an inventory of water resources and demands. During the second phase, certain suggestions were made concerning the institutional framework of the organization for the execution of the plan. In the Kenyan situation, it was also suggested that the major river basins should be used as the basis for planning and a set of development options for the different basins should be prepared and submitted to the Kenyan government. For each of these basins, it was suggested that certain aspects of the following disciplines or areas of study should be examined: climate, hydrology, geomorphology, soils, hydropower, agriculture/irrigation, community water supplies, development options, economic assessment, impact assessment on social, cultural and health conditions, some special problems, and finally organizational and management requirements (ROK 1978c). Checklists for impact assessment in various fields have been developed by, for example, the USAID; but such a list certainly needs revision

to be adapted to the special conditions of each country. For Kenya, for example, a checklist of this type has been developed by Baker and Meadows (1978) for a pre-feasibility study.

When talking about master water-plans, we have to some extent entered the fields of the planning programme that have to do with "defining scope", "setting schedules", as well as "assessing problems and issues". That is because a master water-plan must include feasibility studies, as well as preliminary studies for specific projects. By this is meant that a timetable must be prepared for implementation, financial justifications and cost estimates, etc. for the drainage basin or region in question. An analysis of the legal constraints is always required. All these problems must be studied through a comparative analysis of advantages and drawbacks (cf. cost-benefit analyses in which economic as well as non-economic (social) advantages and environmental aspects must be regarded for the resource protection). However, such a diversified planning procedure requires more and better information than that possessed by many countries. Moreover, the preparatory stages need a considerable amount of time, which may delay the selection of a plan, whereby the economic profitability of the project may be threatened.

The scope of the planning process depends to some extent also on the geographical-hydrological region to be considered. Many factors must be considered before deciding on the area most appropriate for water planning. It has been stressed that the drainage basin itself may be an ideal region for both land and water planning. However, sometimes the regional planning may lead to more adequate results especially when inter-basin water transfers are important.

It may be argued that one basin is often too small to constitute a reasonable object for water-planning resources. There may also be political or constitutional constraints that make it very difficult for the basin to exist as a single, separate unit. In recent years, the growth of major urban areas has sometimes made these much more appropriate as planning units than the basin to which they belong.

ENVIRONMENTAL CONCERN

(1) Countermeasures Have to be Taken — the Sooner the Better

In Chapter 2, we noted that the central role played by water in the ecosystem makes ecological effects inevitable as a result of human manipulations with water circulation in nature. If such ecological impacts of human interference are to be kept as low as possible, they have to be taken into account at an early stage. In other words, environmental-impact assessment has to be included in all water-resources development and should be seen as an integral and continuous part of the planning process (Teclaff 1976c). Two steps have to be taken:
(1) to create general awareness of the problem;
(2) to create tools and strategies to solve the problem.

Awareness has to be created and developed at all levels: the general public; the decision-makers; the planners; and the scientists who have to develop the knowledge on which education activities have to be based, i.e. on the interconnections between the water system and the environment that create the ecological impacts. The UN Conference on the Environment in 1972 greatly contributed to such an awareness. Although environmental concern is at present most developed in the West, where far-reaching ecological damage is the price already paid for industrialization, the problem is broadly recognized also in the developing countries.

A testimony of this is, for instance, emerging legislation (Teclaff 1976b). In response to an ESCAP questionnaire, requesting views on activities needed most in river-basin organization, eighteen countries gave priority — even over water-quality control — to assessment of environmental effects, data collection and flood forecasting, (Teclaff 1976c) etc. The UN Water Conference in 1977 also drew the attention of governments to the important environmental problems encountered in water-resources development and stated that

> "Large-scale water development projects have important environmental repercussions of a physical, chemical, biological, social and economic nature, which should be evaluated and taken into consideration in the formulation and implementation of water projects. Furthermore, water-development projects may have unforeseen adverse consequences affecting human health in addition to those associated with the use of water for domestic purposes."

The tools to be used in the struggle against unwanted ecological damage differ according to the time perspective to be applied: whether to remedy existing environmental damage or to impede adverse effects of a future project. In other words, whether the time perspective is retrospective or prospective. The perspective is retrospective, when suffered impacts have to be remedied from projects which have been decided in spite of the limitations imposed by the environment, whereas the perspective is prospective when projects are decided upon with maintenance of a high-quality environment as one of the objectives. The time scale enters the decision-making process also, in the sense that this process involves a balancing of short-term benefits against long-term detrimental effects.

In the former, retrospective case, much attention has been paid to water pollution and its detrimental ecological effects. Water pollution is a problem of increasing concern to developing countries especially pollution caused by sewage. The primary remedies to water pollution are a cut-down in the amount of waste discharge through changes in the handling of waste, in the production process, or in the recirculation of water, and an increase in, or more effective use of, the assimilative capacity of the receiving waters. On the whole, three approaches are used to stimulate this development towards reduction or elimination of the input of waste: the use of water-quality standards; effluent charges; or financial incentives like subsidies, etc. (Teclaff, 1976a). Evidently, the different stages of general development create a significant difference in the nature of the pollution problem, industrial pollution being the dominant problem in industrialized countries, sewage in developing countries. It might, therefore, be adequate with different guidelines for different regions of the world (Teclaff 1976c). The UN Water Conference recommended a large number of specific activities for countries to avoid and to combat the effects of pollution.

In the future, other types of environmental impact may be increasingly better detected within the framework of an *ex-post* evaluation, implying that a process is increasingly needed to monitor experience in implementing projects and policies.

In the prospective case, environmental concern may be introduced already in the decision-making process by including an impact assessment of environmental damage of a future water project and taking this damage into account through a comparison with project benefits. This implies that attention is paid also to ecological effects in the search for the most favourable among a number of alternatives.

(2) Environmental Impact Assessment

(a) Basic concepts

In the identification of environmental changes caused by human impact three key words have appeared to be essential, namely "environment","ecosystem" and "quality of life" (Munn 1975). Of these concepts, "ecosystem" and "quality of life" will be considered.

The word "ecosystem" is a term that is used to describe a particular level of organization in the organic, as well as the natural world (Stearns and Montag 1974). By "the complete ecosystem", we may refer to a sufficiently diverse set of living and non-living components which is entirely self-sustaining. More essential, perhaps, is the fact that the ecosystem provides us with a model of organization by which a system analysis of the man/environment interaction may be delineated. The "quality of life" concept may be considered as a superordinate concept encompassing the notions of both welfare and well-being. A difficulty may arise when, as Vlachos and Flack (1974) point out, we have to bear in mind that "quality of life" also has to reflect our perception of the human role in "the total environment", which is thought of as being composed of man himself, culture and the surrounding physical environment. They write:

> "By recognizing these key parts we want to examine how men in creating culture affect both their individual lives and the surrounding physical environment. In turn, the natural environment imposes certain constraints as to what man can do and how a given culture is shaped. There is a reciprocal relationship among all above. The term "environment" may thus be defined as the system of spatial, temporal, and social regularities which influence the biological and behavioral processes of a given population."

It is quite obvious that the central idea about man/environment interactions expressed in that manner may be fundamental in understanding the human environmental impact. The serious problem still remaining unsolved is how we can find parameters that are reliable indicators of man's (adverse) effects on the environment. This is apparently the crucial situation, because environmental effects will produce environmental impacts. An environmental effect may generally be understood as a process that will be put in motion or accelerated by human action. Among such effects are the dispersion of pollutants, the erosion of soil or, for instance, the displacement of persons due to urban or other activities. Environmental impacts shall be considered as being the net changes, either good or bad, with regard to human health and well-being.

(b) Impact of large dams

The literature contains many discussions on the adverse effects caused by large dams. Thus, it is observed that vegetation and agriculture below a dam may be adapted to periodic flooding. Moreover, the regime may be altered more or less unfavourably, because fertile silt will not be deposited downstream, but in the reservoir itself (cf. Jackson 1977). A further consequence of this is that water leaving the dam, having just lost its sediment, may cause rapid erosion in the downstream watercourse. Many such incidents have been observed in, for instance, Africa, where the Sadd el Ali High Dam at Lake Nasser may stand as one interesting example. From Central Africa, it is reported that the trapping of silt by Lake Kariba has led to an impoverishment of the Mana Pools alluvial flood plain to some 80-100 km below the dam (Van der Lingen 1973).

Creating large dams is one of many instances where the possibility of making a reliable socio-economic budget may be really doubted. The difficulty encountered is closely related to the problem of counterbalancing tangible and intangible quantities. Unfortunately, we still have no method of comparing such different types of quantities. A very difficult component to consider in such calculations is the health factor. It has been emphasized, for instance, by Obeng (1973), that the incidence of schistosomiasis, has increased to 90 per cent in children under 10 years old on the western shore of Lake Volta in Ghana since the dam was built. The conditions for the spread of schistosomiasis still appear to require elucidation, since no schistosomiasis seems to have been observed on the eastern shore. A comparison with the environmental conditions existing at, for instance, Lake Brokopondo in Surinam, shows that explosions in such diseases as malaria, filariasis and schistosomiasis have not occurred. One explanation may be the acidity of water, as well as low population density (Leentvar 1973).

Another problem in connection with dams is the rapid spread of weeds, a phenomenon closely related to public health hazards and parasitic problems. Lake Volta, for instance, has been quoted as an example of adverse effects just because of weeds harbouring snails, mosquitoes and intermediate hosts of parasites.

Obeng (1977) has devoted much effort to discussing the adverse effects caused in dam building. Her fundamental thesis is that there is need for a multidisciplinary approach to the planning and construction of dams and that ecologists and biologists must monitor contaminating factors. It is, thus, clearly a difficult problem to make dams environmentally safe. One approach would be the organizing of long-term research, surveillance, and assessment of ecological changes, thereby incorporating the assistance of social and community workers.

(c) The seeking of compromises

As examples of difficulties encountered, we have very briefly touched upon some consequences of human activities in reservoir and dam building. To compare advantages and disadvantages in such a case is — with current evaluation techniques — practically impossible. So the way we have to handle the question is to maximize the advantages and minimize the disadvantages with some presupposed constraints as to health, etc. It goes without saying that special skills are required to perform such a procedure and, as Obeng (1977) has pointed out, a multidisciplinary approach must be aimed at.

This statement may perhaps be perceived as self-evident; but the real difficulty, to apply it in practice, has to do with the inherent complexity of the situation. Let us imagine that a series of variables may be processed to produce a desired output. The simplest way of illustrating this mechanism is through the black-box principle. A series of feedback impulses exist in this scheme, especially from output to input as well as to the through-put (the black-box system). Thus the desired end product closely relates to the two earlier components.

One further link in the chain of environmental impact assessment has to be considered: what will be the effects of the desired output on the environment? Here we must also consider feedback loops from environment to output, throughput and input. These, together with the feedbacks already mentioned will reveal how complex the two-layered system really is. What in fact has happened is that constructors of man-made systems (for instance, man-made lakes) very often have disregarded precisely these joint environmental effects, more or less because they are so difficult to foresee. Consequently, engineers and constructors generally present a plan that fulfils desired wants without considering what environmental effects may arise. There is no simple way out of this controversy. Only a multidisciplinary team of skilled scientists and practitioners may help to find

the right way through mutual checking of difficult passages. There are, in fact, very many programmes that are on-going or recently completed. For instance, the experience of the Volta and the Barekese reservoirs in Ghana is being used when considering the environmental impact of the Weija project which is planned to provide the water supply of Accra. Another example may be taken from Malawi, where the effects of the operations of the Kamuzu barrage on the ecology of Malawi's national parks is considered. Again in Malawi, a survey has been performed as to the risk of ecological degradation in view of the pulp industry (ECOSOC 1976a). Furthermore, studies have been carried out in the Sudan, where special attention has to be paid to reservoirs with regard to the physical, chemical and biological characteristics of river water.

(d) Present trends

Environmental-impact assessment has successively gained increasing importance in developing countries. Thus, special organizational units for attending to environmental problems have been set up. In particular, it may be mentioned that the National Environmental Secretariat in Kenya coordinates the activities of all the ministries concerned, including informing the public about the need to protect and improve the environment.

As indicated earlier, there are no general rules that take into account all aspects of environmental impacts due to water-resources activity. It is hoped that an interdisciplinary approach will be the way by which a specific problem will be solved. Without striving for generality, the following four sequential steps of an assessment of environmental impact may be borne in mind (Fischer and Davies 1973):

(a) identification of planned and induced activities;

(b) identification of relevant elements of the environment likely to be altered;

(c) evaluation of initial and subsequent impacts;

(d) management of beneficial and adverse environmental impacts that are generated by the planned and induced activities over time.

CHAPTER 5

Conflicts over Water

> Rain falleth upon the just and the unjust alike, but irrigating waters reach the fields by channels that the community has constructed. And what society has provided, society can also withdraw from the unjust and confine to the just alone.
>
> Gordon Childe, 1946

INTRODUCTION

Many of the problems discussed earlier in this volume cause conflicts. There are conflicts over visions and aims: irrigation schemes may be planned for high cash returns from sophisticated agriculture, but local populations may be unsophisticated and more interested in survival and food production than in cash crops. There are conflicts between governments and the people they govern; many of the rich and influential people in society have a vested interest in the continuation of poverty; there are conflicts between rich and poor and between rich and the bureaucracy, and in the decision-making process in general.

An important aspect in water-planning and water-resources research is to be aware of such potential conflicts and to devise methods to alleviate or prevent conflicts from occurring.

We have, therefore, considered it useful to look at some water problems in terms of the conflicts they create. Conflict is a constant feature of society and societal conflict has been the focus for a substantial body of research in the social sciences, especially during the late 1950s and the 1960s. It is not the intention here to develop a typology of conflicts, but some preliminary remarks may be in order.

According to "classical" conflict theory (Coser 1956, Boulding 1962, Simmel 1955) conflict is looked upon as a form of social interaction, a struggle over claims to scarce resources (power, status) in which the aims of the opponents is to neutralize, injure, or eliminate rivals (Coser 1956). Conflict is usually conceived as being different from competition, and there are several cognitive layers of conflict. A constant state of competition — as, for example, all organisms dependent on water — is not necessarily conscious and has therefore also been termed

meta-conflict or indirect conflict (MacIver 1937). Direct conflict, "real" conflict, "open" conflict, is always a conscious process, where parties perceive that they are competing for scarce resources or believe that they are in conflict with some other party over this resource. Such conflicts can be predicted, and some of the material below concerns areas of potential conflict.

When an open conflict is at hand, there is almost always a tendency at the same time to find a solution to eliminate the conflict. One aspect of planning in the widest sense of the word is, of course, to identify potential conflict areas and plan for their solution. Solutions may take many forms, ranging from the elimination of one party to various types of compromises. Compromises may either involve a redistribution of negative values or may take other forms. Such conflict-solution mechanisms are of great interest and certainly worth more attention in the water-research field. What forms does the compromise take? How far from the optimal solution (objectively, if that can be assessed, from the point of view of the contenders) are the acceptable solutions? What is an acceptable level of conflict over water? What are the consequences, and indeed the reach of different mechanisms? To whom are the negative values transferred, and who has to give in?

Some generalizations may also be possible concerning types of conflicts in development which are important also in terms of water development.

One aspect is a *conflict over visions* of the future, of what rural life should look like, or contain, or be concerned with. Such a conflict, which often is very difficult to pinpoint, is the undefined background of much societal conflict.

The undefined and diffuse ideas of most development agencies, and indeed governments in developing countries, that development is something that should strive to emulate other, technically more advanced societies, has occasionally produced schemes that are based on high capital investments to produce high cash returns from sophisticated agricultural systems in societies where the largest part of the population are smallholders, landless labour and rural poor in various service occupations (Hunter 1978). Such an insensitivity could lead to a further problem: projects which have succeeded in a more favoured part of the population are put into practice without considering the remaining part of that society, the mass of the rural poor. The project orientation of much development work is certainly in conflict with a more holistic vision or approach to rural development. Another example (Hunter 1978) is the belief that small farmers in densely populated irrigation areas have a high intensity of production. In fact, in many areas population growth and fragmentation of holdings have created conditions which long ago ceased to be conducive to intensive agriculture.

Experts and scientists from the outside very often correctly point out examples of ecologically disastrous irrigation, agricultural or cattle-rearing practices, which will lead to the destruction of the environment.

The social reality of rural life is that survival is almost always at stake. Therefore, the prevalent economic "philosophy" is an opportunistic utilization and maximation of resources in the short term. (One might be tempted to compare the present world market and pricing system: the price mechanism is marvellously subtle at adjusting to short-term shortages and surpluses, but hopeless over the long-term. Both systems discount the future at a very high rate).

Very poor people cannot be expected to take an especially responsible attitude towards tomorrow and a forthcoming ecological disaster when they are engaged in the struggle to achieve small elementary progress today.

The social reality of survival, the "subsistence ethic" (Scott 1978), makes experimentation and acceptance of new untested techniques a kind of game with one's life at stake. This also means that the modern world is often frightening, and modernization is not at all conceived as the way to a better life. Development is a cruel choice. For example, land inheritance systems are almost always in conflict with modern perceptions of efficient agriculture which include consolidation of fragmented holdings. Many superficially odd village practices make sense as disguised forms of insurance (Lipton 1968).

Within a village there are almost always some social arrangements to ensure survival of its members (minimum income, minimum food). One should not romanticize such social arrangements, but they are very real and are experienced as a pattern of moral rights or expectations (Scott 1978). This idea was developed by Barrington Moore (1966): "This experience (i.e. that of sharing risks within the community) provides the soil out of which grow peasant mores and the moral standards by which they judge their own behaviour and that of others. The essence of these standards is a crude notion of equality." Violation of such standards provokes resentment, resistance and conflict.

It is, therefore, important to stress the difference between the urban middle-class outlook and social reality on the country side. Another world begins at the level immediately above the lowest administrative divisions. The inherent order in local systems of knowledge and ethics has to be understood. Frequently it is not (Warren 1976). Geographers would relate this to a different concept of spatial organisation or spatial sensitivity (Krokfors 1978), the insider's way of knowing a place and the outsider's conventional way of describing it (Buttimer 1978). Sociologists would call it a variation of the classical sociological dichotomy between *Gemeinschaft* and *Gesellschaft*. However, whatever the name, the problem still remains.

New techniques and *new technology* may cause innumerable conflicts, as will indeed the belief of engineers in the efficiency of modern technology. But this is really not a question of whether the technology is modern or not, it is more a question of the effects of technology (Burton 1974).

To control such conflict-generating effects is not very easy. The relation between man and technology is extremely complicated and human control over technology can only be achieved through organizational solutions. If such organizations or institutions do not exist, technology can be a potential menace to societal development.

It is important to remember that technology does not only mean engineering technology. New credit systems in agriculture (and ensuing default) new types of education and training may also have the same effects as indeed government control methods, water rationing, etc.

New technology also creates a widening gap between rich and poor generally and may also exacerbate other forms of inequality such as urban-rural differences and inequality between regions, national or international. So many development projects conceived against a background of middle-class urban elite values have caused increased poverty in other sections of society, that it may be conjectured whether some members of society have a vested interest in a poverty situation and do not want it changed (Hunter 1978).

Conflicts can be looked at in a variety of ways. For our purpose we have chosen a hierarchical organisation of the types of conflicts we are going to discuss, from international conflicts to conflicts at the local level. Much of the discussion also concerns situations with a conflict potential.

CONFLICTS OVER INTERNATIONAL RIVERS

(1) The Basic Problem

The first type of conflict is in fact geographically based and embraces the conflicts apt to develop during the course of river-basin development in basins shared by several countries. One would imagine that joint interests in realizing flood control and avoiding water pollution should create a spirit of cooperation between co-riparians but the opposite seems to be more common. The vast size of this problem is now being increasingly recognized and Utton's recent paper (1978) constitutes a good basis for our discussion.

The basic cause of conflicts is evident. Measures taken by upstream countries influencing the river flow diminish the possibilities of downstream countries to use the river for their development. Upstream measures can imply permanently or seasonally reduced downstream flow, and therefore decreased river-water levels, with all the direct and indirect consequences this may have for water-dependent activities in agriculture and industry. They may also imply deteriorating river-water quality, thereby introducing serious water-supply problems. Such conditions may result in political controversy and sometimes lead to serious consequences.

At the same time, there often exist joint interests to develop the river, to harness its hydropower, to regulate the flow in order to reduce flooding and increase dry-season flow. The profile of joint interests may, however, look very different to the upstream and the downstream country. It also changes during the course of time. As the final decisions have to be taken by the governments involved, the negotiation process may turn out to be very lengthy indeed. The end product may be a water treaty recommending certain basic philosophy in the river development, which in the end is not at all followed in the respective government decision-making. Had, for instance, Canada and the U.S.A. followed the Boundary Waters Treaty of 1909, prescribing in article IV that "boundary waters (waters flowing across the boundary) shall not be polluted on either side to the injury of health or property of the other", today's water pollution problem in these waters would be non-existent (Utton, 1978). Evidently the pressure to follow treaty recommendations is often overruled by technological development, and national interests rationalized behind the principle of sovereignty.

(2) The Size of the Problem

The problem of international rivers is by no means a minor problem. In fact about 1,500,000,000 people (1973 population) i.e. close to 40 per cent of the world's population live in international river basins and are dependent for their long-term socio-economic development on a prospective cooperation with the co-basin states.

The problems of international river basins are receiving increased attention by the international community. A recent UN inventory of river basins shared by two or more countries (UN 1977d) reveals that there are 214 such basins, Table 5:1.

TABLE 5:1

INTERNATIONAL RIVERS DISTRIBUTED IN TERMS OF NUMBER OF COUNTRIES SHARING THE SAME RIVER BASIN

Number of co-riparian countries	2	3	4	5	6	7	8	9	10	12
Total number of rivers	155	36	10	3	3	1	2	2	1	1
Name of rivers shared by five or more countries				—La Plata —Ganges and Brahmaputra —Elbe	—Volta —Lake Chad —Nelson	—Amazon	—Zambesi —Rhine	—Nile —Zaire/ Congo	—Niger	—Donau

The regional distribution both of international river basins, the degree of complexity and the total population concerned is rather uneven, cf. Table 5:2. (The population estimates are only rough and refer to 1973 population). The table also reveals the degree of mutual interdependence of the countries as reflected in a considerable number of treaties and agreements on issues of common interest.

TABLE 5:2

INTERNATIONAL RIVERS BY CONTINENTS

Continent	Estimated population (million)	Total number of international river basins	River basins shared by four or more countries	Number of treaties 1972
Africa	270	56	12	34
North and Central America	90	34	—	38
South America	100	36	2	31
Asia *ca*	600	40	5	31
Europe	330	48	4	175
Total *ca*	1370		23	309

The regional differences are evidently very large. Whereas both the total number of river basins and the complexity is greatest in Africa, the number of treaties is still quite low in that area. The latter is true also in Asia, where the size of the concerned population culminates. The higher degree of river-basin development in Europe, where the number of international rivers is quite large in relation to the area of the continent, is reflected in a considerable number of treaties. In conclusion, the problem of sharing international river basins constitutes a very central development problem in the regions especially considered in this report.

(3) Traditional Means for Solution of Conflicts

The only way of avoiding conflicts created by such mutual dependence on the same water resource is, of course, by constructive cooperation between the countries concerned. There are, however, numerous obstacles to such cooperation: differences in incentives, sovereignty considerations, unsatisfactory institutional structure, etc.

The degree of generality is not very large, as each river basin presents its own problem profile. This is primarily governed by the geographical configuration between the co-basin states: Sequential river situations with clearcut upstream-downstream positions of countries contribute to the problems by large differences in incentives. In some cases, the downstream country can to some extent be seen as a prisoner, fully dependent, and without power to impede on measures taken in the upstream country, which in its turn has no economic incentive to pay regard to impacts on downstream water uses (Fox and Le Marquand, 1977). The incentive situation is different, if the river forms the political border or the border swings to and fro across the river. In such cases, the countries are at the same time upstream and downstream countries in relation to each other (Utton 1978).

Considerable differences between individual river basins for geographical, social and cultural regions contribute to the difficulty of the development of international law giving guidelines for the solution of conflicts of interests.

In general, there are two principally different aspects on problem solution: problem solving in advance, as part of a joint river-planning and development process, and *ex-post*, i.e. when the damage of some action has already developed. The general tool for prospective action is the international river-basin commission in which the countries act jointly in a more or less constructive process based on joint treaties and agreements. The tool for remedy action in the retrospective dimension is decisions in international appelate courts based on principles of international law. Also in the prospective case, of course, the principles of international law form a general conceptual base, and provide guidelines for agreement.

International practice, as evidenced by treaties, conventions, and declarations, clearly demonstrates that the basic principle of absolute territorial sovereignty is not adhered to (Utton 1978). This doctrine has in fact been modified by influence from the other extreme doctrine expressed by the Roman maxim *sic utere tuo ut alienum non laedas* (so use your own property as not to injure your neighbour). The resulting doctrine is expressed by a "fair-share" concept of equitable apportionment of the water resource, implying that benefits are balanced by cost or damage incurred on other co-basin states. The ideal of this equitable utilization principle is that the resource should be utilized to satisfy the needs of the co-basin states to the greatest extent possible, thereby maximizing the benefits and minimizing the detriments to each. This doctrine is expressed by the Helsinki rules, which constitute general guidelines accepted by the International Law Association in 1965 after ten years of preparations.

In order to apply on a continuous basis the principle of equitable share, the co-basin states normally establish a joint international river-basin commission. Lessons from the experience of nine such river-basin commissions have been summarized by Fox and Le Marquand (1977) in preparation for the UN Water Conference.

(4) Some Key Problems

(a) Vagueness of the equitable share principles

The general situation concerning joint use of international rivers may be considered to be vague not only due to the rich individuality from basin to basin, but also to the vague status of the basic principle of equitable utilization which is no more than a set of recommendations from a non-governmental scientific organization. Also, the content of the principles is disturbingly vague and uncertain and in fact nothing more than an appeal to the international conscience (Utton 1978).

(b) Time aspect

The distribution of benefits and damages to the countries involved in an upstream-downsteam relation changes over time, and so, therefore, do the implications of the equitable share concept, see Table 5:3.

TABLE 5:3

BENEFIT-DAMAGE RELATION AT DIFFERENT TIMES

Zero situation	Intended change	Benefit to	Damage to
natural	upstream exploitation	upstream	downstream
exploitation already realized	reduce damage in downstream country by limitation to upstream country	downstream	upstream

Such time effects would, in fact, strengthen the incentive of the upstream country to avoid entering into negotiations at a too early stage. The *fait accompli* is a much more favourable starting point. Also the technological change contributes to a more or less continuous change of the mutual situation and the implication of the equitable share concept.

(c) Persuasion rather than coercion

As the decision-making always stays with the individual government, the role of such commissions is persuasive rather than coercive (Utton 1978). As long as supranational drainage-basin authorities are largely utopian, the catalytic action developed by more realistic regional commissions has to find its optimal form. The tools at their disposal are acquiring information, building a foundation of mutual trust and confidence, formulating policy and disseminating it to co-basin states. The power to persuade has to be backed by detailed knowledge, but the possibility of persuading depends heavily on the incentive/disincentive pattern. Fox and Le Marquand (1977) divide them into three main types:

(1) benefits to one do not impair benefits from similar use to the other (e.g. navigation);

(2) use by one diminishes potential benefits from similar use by the other (e.g. withdrawal, waste disposal);

(3) benefits to all by undertaking integrated river development (e.g. flood control, hydropower production).

Two aspects are crucial in the persuasion process carried out by river-basin commissions (Fox and Le Marquand 1977):

(1) There is no substitute for the will to cooperate. This is a question of motivation, created by an adequate pattern of incentives and disincentives. To develop this pattern, imaginative ways of sharing benefits and costs have to be explored.

(2) It is of critical importance that each riparian country not only understands fully the implications of the schemes under discussion and their physical, economical and social consequences, but is also capable of assessing by itself the consequences of alternative courses of action.

(d) Need for an international code of conduct

Adequate ways have to be found to persuade governments to act in line with the equitable share principle. Even if the persuasion is conveyed primarily by the river-basin commissions, they have to be backed up by some sort of global support. There is, therefore, a clear need for a global advisory body to take on international leadership by giving advice, developing a code of conduct that would, in the long run, persuade governments to follow the principle of equitable sharing and helping to clarify its implications in different situations.

In the field of shared water resources, research activities are badly needed. Persuasion can be foreseen to be a very slow process, taking into account the primitive views that are being expressed in today's world in the field of shared water resources. Therefore possible positions of governments have to be analysed. Much imagination has to be devoted to developing new forms of incentives and disincentives. Constructive ways of developing a more open-minded approach by governments in their sovereignty decisions have to be created.

SOME ECOLOGICAL CONFLICTS

Again, this is a conflict over visions. We have already discussed the ecological implications of short-term maximization of scarce resources in general.

In water-resources development the short-term benefits vs. long-term deterioration is a planning problem with a heavy political bias. In situations when rapid industrialization is considered necessary and is a priority of the government or the market place, very little consideration will be given to costs and investments in pollution control. Indeed, when donor agencies and experts raise such questions the answer has been that ecological concerns, the prevention of industrial waste in the air or in water, and such additional considerations which carry extra costs are nothing but a neo-capitalistic trick to keep budding industries in the developing countries down and out of competition. Needless to say, this situation has been used by many hazard-exporting multinationals eager to get away from expensive pollution-control systems in the Western world (Castleman 1978). The understanding of long-term effects seems also to be rather poor among local decision-makers in developing countries.

Even medium-term effects, say up to ten years, seem difficult to handle.

The impact of indiscriminate destruction of the forest in the upper reaches of Tana River in Kenya has increased the silt load which in turn fills the dams at the Seven Forks hydropower installations and makes them useless in ten to twelve years. The lack of interest in drainage or the administrative inability to cope with such problems makes irrigated soils useless in less time than that, through waterlogging or salinization.

The water situation in Coimbatore, Tamil Nadu, India is another case in point. The situation is that infiltration into the groundwater is less than what is being used for irrigation and the water balance is unfavourable. Although this over-exploitation is quite clear from the sinking groundwater level (25-30 meters in the last ten years) it has been almost impossible to introduce any legislation on rationing or conservation of the groundwater, not to speak of voluntary restrictions among the farmers (Gustafsson *et al.* 1970). The long-term effects are probably understood, but until the water disappears, it is hardly likely that anyone is going to do anything about the situation.

Thus, the complexity and non-static character of human attitudes in itself introduces a conflict in water-resources development, namely the dilemma between on the one hand paying so much attention to considerations of short-term benefits that serious long-term impact will shrink the possible life-time of a project and even cause irreversible damage on soil productivity, and on the other giving so much weight to sophisticated views on many long-term impacts that the views of local people are forgotten. It is evidently necessary to strike a good balance between these two extremes in developing a fruitful participatory democracy in water-resources development. From this aspect, *ex-post* evaluation of projects should be considered an absolutely essential tool to monitor any environmentally detrimental results of water-development projects. Evaluation could even be made part of a continuing planning process that puts a high value on flexibility. In fact, a rather innovative method, called contingency planning might be of interest in this connection. It implies that continuation of the work within a project is predicated on the presence or absence of certain environmental effects as the project develops (Teclaff 1976b).

Strategy for possible solution-mechanisms and for larger environmental concern in developing countries is evidently crucial. Such strategies could include the philosophy underlying the evaluation process, and the nature and extent of the public's involvement (Teclaff 1976c). The 1976 UN Water Planning Seminar made several suggestions in these areas: countries should strive to develop machinery for environmental-impact assessment of water projects, and whenever possible develop legally mandated procedures in this direction (Teclaff 1976a). Knowledge and information should be broadened on environmental aspects, and environmental policies be integrated in the planning process (Fogel 1976). Environmental improvement should be regarded as one of the multiple objectives of planning and developing countries should set their own priorities based on their cultural and social values. Interdisciplinary representation among water planners and decision-makers is most important. Many of the detailed recommendations of country action by the UN Water Conference follow the same lines (UN 1977a).

Taking the numerous methodological problems into account, together with the lack in many countries of adequate financial resources and adequate administrative machinery for the complex evaluation and balancing of environmental and non-environmental factors, international organizations could not do much to facilitate this task (Teclaff 1976b). The UN Planning Seminar proposed that environmental impact statements be routinely included in every international river-basin project funded or assisted by UN bodies. Also the UN Water Conference recommended international organizations and other supporting bodies to contribute to assessment of the environmental impact of water projects and help to take suitable action to prevent undesirable consequences.

CONFLICTS AT THE MINISTERIAL LEVEL

(1) Introduction

Conflicts between ministries exist in all governments. They are caused by different opinions of areas of competence, imprecise legislation, administrative overlap, etc.; and, moreover, in developing countries with rather small elites, personal differences are not unheard of, nor divisions along ethnic lines.

Some such conflicts often take subtle forms and are thus rather difficult to perceive. Others come out into the open. It may be useful to divide the discussion of such conflicts or areas of potential conflict under three headings:

(1) Conflicts between major administrative divisions, between policy makers and bureaucrats, between executive and parliament.
(2) Upstream-downstream conflicts channelled via or expressed by major administrative divisions.
(3) Special water demands and their conflicts.

(2) Administrative Conflicts

Classical conflicts in irrigation administration are caused by the division of the irrigated area into one sector under the Ministry of Irrigation — main channel, lower channels, O and M of major channels, construction etc. — and one sector under the Ministry of Agriculture — field channels, drainage, agricultural expansion.

The classical case has been irrigation administration in Pakistan and India. The anomalous situation which prevailed in India was one of fragmented administrative organisation. Irrigation was divided between the Ministry of Irrigation and Power and the Ministry of Food and Agriculture. Prospecting for groundwater rested with the Geological Survey of India in the Ministry of Mines and Metals, but responsibility for proving its existence rested with a drilling organisation located in the Ministry of Food and Agriculture. There was no single authority which could act as a focal point (Vohra 1975). Furthermore, development for water resources was and is still the responsibility of State Governments and construction, planning, and running of irrigation works are done by Departments of the State Governments.

At the national level, the Ministry of Irrigation and Power deals with major and medium irrigation works and the Ministry of Agriculture with minor surface irrigation and groundwater schemes. At the state level the responsibility of the irrigation departments ends with the construction of reservoirs and the main distribution systems. Below the outlet, the cultivators are responsible for building channels, shaping land and looking after the drainage with such help as the Ministry of Agriculture can give them through their extension departments. A Joint Working Group of the Ministries of Food and Agriculture and Irrigation and Power was set up in 1963 to look into the irrigation administration problems and a major reshuffle of ministerial responsibilities in 1974 brought irrigation into the Ministry of Agriculture.

A Groundwater Board was also created. The Agricultural Prices Commission of India (1974/75) pointed out that the decreasing yields since 1970/71 largely depended on the irrigation methods not being able to cope with the demands of the High Yielding Variety (HYV) seeds. This report and a variety of other bodies (for example the Irrigation Commission (1972) and the National Commission on Agriculture (1973)) triggered off a new development in irrigation in India, the so-called Command Area Development Programme. The main idea was that the Command Area Development Authority should be either a body with command over all the

departments involved in irrigation, or, where this was not possible, to have a coordinating function. This programme, to which several objections can be raised, such as the permeating idea that irrigation is the preserve of engineers and that very little attention is given to the real administration and operation of programmes, may have solved problems in some states. There is, however, still a need for a National Water Resources Council (Chaturvedi 1976) with over-all responsibility for irrigation, flood control, hydroelectric development, navigation, etc.

The major conflicts in the old system were over responsibilities of the ministries. The Agricultural Extension Service was not equipped to give advice to all farmers concerning their land and field channels and certainly not concerning drainage. Again, drainage has to be done in order to prevent waterlogging and salinity problems, but it cannot be done properly unless there is a total drainage plan for a whole area or block. This, in turn, involved the construction of major and medium drains by State irrigation departments (Vohra 1975) which they contended they had neither reason nor authority to do.

In Pakistan, regions have the main responsibility for agriculture and irrigation policy. An authority at the central or federal level — The Water and Power Development Authority — is responsible for much construction and planning, but not operation of irrigation and other water installations. The same division of authority applies here as in India before 1974: irrigation departments have the responsibility up to the *mogha* or outlet; below the *mogha*, the farmer is generally on his own or perhaps helped by the scanty resources of the Ministry of Agriculture (Mirza *et al.* 1975, Corey and Clyma 1975). One potential area of conflict is that in irrigation matters, officials of the various agricultural departments play a subordinate role to officials of the irrigation department. Again the WAPDA mentioned above has more funds and more glamour, and consequently attracts better people and ranks higher than the O and M people of the irrigation departments. The lack of communication between such organisations makes planning a theatre of the absurd, with no regard to the needs for maintenance nor to administrative problems of operation and management. Both the departments of Agriculture and of Irrigation are heavily underfinanced and there is a constant quarrel about responsibilities, for example about drainage problems. The stress on the glamour of new construction, the financial problems of departments and their limited cooperation creates an anti-drainage bias in the operation of the whole system. Thus costs for drainage are always underestimated and when irrigation schemes overrun their budgets — which they always do — there is little money or interest left for drainage. "The legacy of this continued defiance of reality is a stupendous loss of global agricultural output" (Eckholm 1976).

The Mwea scheme in Kenya has been described in a volume edited by Chambers and Moris (1973). One of the aspects of this scheme is that it is a planned settlement scheme on land which previously has not been irrigated. Like many other African schemes, the settlers on the scheme are only tenants, and the management of the scheme is organized in one single body. Such schemes are today in Kenya under the supervision of the National Irrigation Board, created by the Irrigation Act of 1966.

Before independence, three different departments were involved in running the scheme: Department of Agriculture, Department of Public Works and the Provincial Administration. According to Giglioli, who has described the Kenyan irrigation organization in the above-mentioned study on Mwea, this proved a fertile ground for bureaucratic antagonisms: the Department of Agriculture had the financial responsibility and looked after the day-to-day control of the agricultural activities, Public Works were the design engineers and contractors and Provincial Administration dealt with settlement, settlers and labour. All the departments had different objectives: maximum agricultural production, or design for design's

sake of irrigation installations or security. A constant struggle existed between the departments to achieve managerial control of the scheme.

Again, as Giglioli (1973) puts it "the crash nature of the programme gave all concerned an accelerated course in the wrong ways of going about the job". This is — incidentally — a common feature of such programmes, hence the name "crash programmes".

It took twelve years to establish a National Irrigation Board and to sort out the potential, and sometimes very real, conflicts in the irrigation administration. Still, the civil service is not much in favour of parastatals, and as the number of "boards" and "authorities" grow in the Kenyan water administration, there has been a constant pressure to bring such boards in line with civil service practice. This again opens up new areas of potential conflict.

In Tanzania, several large parastatals work in the water and agricultural field. They are national and operate nationally. However, in a political setting which stresses regional diversification and regional decision-making, planning is basically regional. So indeed, are water and agricultural plans. This means that there are whole armies of uncoordinated civil servants in the field: those from parastatals, those from the regional authorities and even some from the central ministries in Dar es Salaam. In several areas, conflicts have developed over different opinions of the aims of the development effort in water exploitation and the objectives of certain programmes.

Another aspect of the irrigation-agriculture administration problems (where we take the example from Egypt) is the large number of autonomous or semi-autonomous authorities operating within a single ministry, the Ministry of Agriculture. Some are similar to the Kenyan "boards", others completely different. The problem is that such bodies operate more or less independently with competing claims on the resources available to agriculture. Project priorities, the agreement of aims and objectives, and indeed the continuity of schemes, programmes and projects, depend on the relative strength of a given sub-unit rather than on national priorities. Lines of communications between sub-units are, of course, weak or non-existent. The net result of this type of conflict is that small units cannot compete with the large ones and some sectors, therefore, get very little financial power.

Quite clearly, the remedies or solutions for the conflicts described above have been and/or should be administrative reconstruction. The creation of a National Board of Irrigation, the setting up of a Command Area Programme, the setting up of a Lake Victoria Catchment Area Authority in Kenya (*Daily Nation*, Dec 13, 1978) or a River Basin Authority, or even a National Water Resources Board means much to alleviate interdepartmental strife.

More difficult are the conflicts and disagreements over national policy, expressed in terms of allocation of funds for different purposes. The Middle-East wars, as indeed the wars between Uganda and Tanzania, between Eritrea and Ethiopia, create innumerable problems in a weak economy, when the national effort is channelled from agriculture and self-sufficiency in food to aggression and total waste.

Other conflicts between ministries of finance and ministries of agriculture have concerned the different ideas of the use of scarce foreign currency for water installations, spare parts etc. This is, of course, not a conflict only in terms of water exploitation, but a constant conflict between the finance arm of government on the one hand and almost everybody else on the other.

But it is important to mention such conflicts here, as they are sometimes taken to be the reason for not spending on, nor thinking about, operation and maintenance of water supplies.

Spare-parts problems have also been acerbated by border closures, import stops, and the peculiar situations when the ministry has no more funds allotted to pay the customs fees for imported material.

A general problem in water planning which causes conflicts in many aspects is a tendency for *adhocracy* in planning and operation. For example, one ministry is given the order to abolish second-stage cooperatives and cooperative unions. Suddenly, the cotton is harvested and the cotton has to be processed. As there are no unions, there is no transport. Urgent requisitions of lorries are made to "save the cotton crop", and water projects, parastatals, irrigation schemes and industry are denuded of transport, the economy suffers, and conflict is ripe.

(3) Upstream-downstream Conflicts

The problem of international rivers is again reflected at the national level and there are a variety of similar conflicts. Most Indian states have rivers which they share with other states upstream and downstream. Ian Carruthers has shown, with an example from the Athi and Tana rivers in Kenya, how agriculture now has to compete with growing demands of urban populations (Carruthers 1977) (which we follow up closely in the next paragraphs).

Urban water supplies will often take precedence over rural needs, because the water sources that otherwise are available for urban populations are often polluted, or distant. The difference between urban and rural populations and the conflict which occurs when rural people see their water polluted and their rivers depleted, when their own needs are rising, is an aspect of the constant conflict between urban and rural peoples (Lipton 1976).

The Tana river and the Athi/Galana river discharge into the Indian Ocean. They are not big by international standards, but they are vital to Kenya, providing water to Nairobi and Mombasa. They also contain almost all the available hydropower potential in the country. The demands on these rivers are shown below, Fig. 5:1.

Both rivers rise in high altitude forest and pass as small streams through densely populated areas with, at present, insignificant abstraction for farm purposes. The potential in this area for irrigated terraced agriculture is immense and demand could exceed the total discharge of the river at peak periods of demand. The rapidly growing city of Nairobi takes its water from the Athi, and returns it again, heavily polluted. This constitutes a hazard to downstream users such as the estates which produce economically important crops such as coffee, pineapple and horticultural export crops. Hydroelectric schemes are now being constructed at great speed along the Tana and they need storage water to ensure that water is available at peak demand periods. Probably, their demands have priority over most other demands on the river.

The Indian example is a case in point: in large commands there are inherent conflicts between the objectives of improving predictability of water deliveries, appropriateness of water deliveries in relation to crop needs and the equality of water deliveries per acre. When a reservoir canal system is linked with a hydroelectric scheme, these objectives are still more difficult to attain, since water releases from the reservoir are determined partly by the demand for electricity rather than solely by the requirements of agriculture (Wade 1975).

The semi-arid area along the Tana is now planned to be settled with large irrigation projects as pressure on the land increases in the upper catchment. The cost for resettlement will be enormous — up to Ksh 160,000 per hectare or perhaps Ksh 200,000 per family ($US 1 = Ksh 7). The water withdrawal is also conditioned by the releases of the hydroelectric installations.

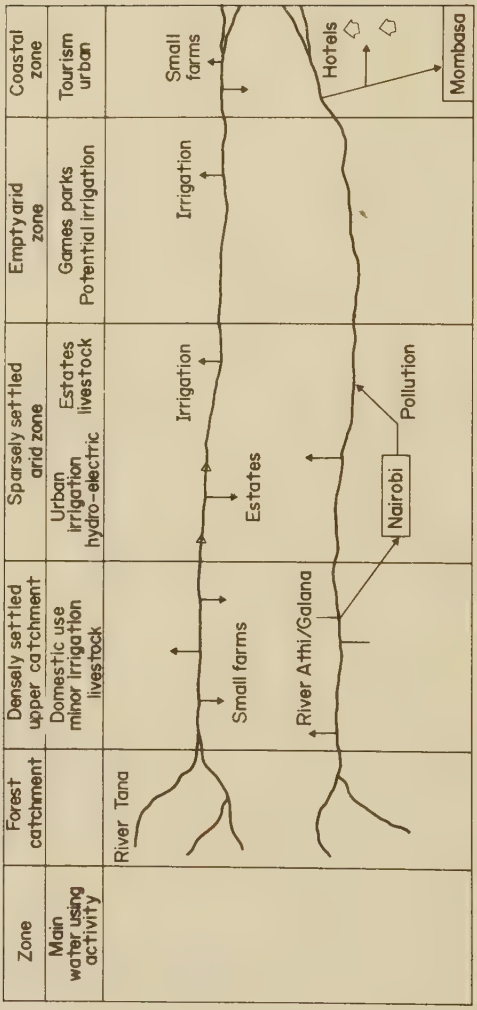


Fig. 5.1. The various demands on the limited amount of water in the Tana and Athi rivers in Kenya. Source: Carruthers 1978.

Pastoral peoples use these rivers for their cattle, and they are also important for the water needs of wild game. If development in the upper parts increases, this could stop the supply for the semi-arid lands. Carruthers also mentions that if this seems unlikely, one has to remember that the Indus and other much larger rivers now fail to discharge to the sea for several months of the year.

More serious again is the situation along the coast and for the city of Mombasa. This is also the area of a new, and growing tourist industry dependent on adequate and reliable water supplies.

> "The outcome of the conflicting demands upon scarce river water (and groundwater) is that it is likely that the era of plentiful 'free' clean water is now over. If, in many developing countries, a 'water scramble' is not to follow the current scramble for land, extremely wise consideration of the technical, financial, economic, political, legal and administrative issues is imperative. Indeed, given the irreversible nature of many water resource developments, it is essential that considerable foresight is exercised if desirable future developments are not to be pre-empted by satisfying ill-considered, short-term objectives. It is becoming evident that in many countries the sum of known water demands too often exceeds the present supply at critical times of the year. Determining priority needs is essentially a political decision, but the decision makers will require better plans and more information on the impact of alternative strategies" (Carruthers 1978).

Furthermore, all the activities, demands, and planned development mentioned above are administered or discussed by different ministries or authorities, often independently of each other and of national over-all planning (Baker and Meadows 1978).

CONFLICTS BETWEEN "GOVERNMENTS" AND FARMERS

> That officer will not listen to me because I have no strong relative, influential friend or a bribe.
>
> Urdu proverb.

In most cases, a government agricultural or planning policy does not coincide with the individual farmer's perception of reality, nor his wishes. There are many potential areas of conflict between "government" and the individual in the water field. Government is here taken to mean all government institutions. We would like to discuss these problems under two headings: one more general — government policies vs. farmers — and one more specific — conflicts in water administration.

(1) Government's Cotton vs. Farmers' Bread

The main point here is that farmers may be more concerned with survival and thus prefer to grow food crops or pay more attention to such crops than the cash crops of the scheme or programme. Government is interested in marketable surplus, and may be also the smooth running of things. Other actors interfere in this "social arena" (Harriss 1976). Let us give some examples.

(a) Government agricultural schemes

The conflict between the government's cotton and the farmers' bread is described and analysed by Tony Barnett (1977). Later in this chapter, the relation between more wealthy farmers growing *durrah* on the side and the low-rank administration will be discussed. Here we want to discuss another conflict-generating aspect: agricultural extension in irrigated agriculture.

The Gezira scheme in the Sudan is one of many development agricultural schemes devised a long time ago by the then colonial government. Many such schemes were set up in the 1920s and 1930s. After the Second World War, when there was widespread disillusionment with the slow pace of traditional extension work, several new schemes were started. Mwea in Kenya was one such irrigation scheme, others not based on irrigated agriculture were the Ground Nut Scheme ventures in Tanganyika, The Native Land Husbandry Act projects in Rhodesia and the Swynnerton Plan Projects in Kenya. All these activities, as well as many others (like the creation of a *paysannat indigènes* in the Congo), were based on the philosophy of creating "progressive farmers" (Johnston 1964, Moris 1967, who we follow here). Kay writes on the Rhodesian scheme:

> "It was decided ... that in addition to normal extension work an 'impact scheme' should be introduced whereby progressive individuals could be relieved of the economic and social difficulties of village life and equipped with the land, capital and technical assistance necessary to enable them to become advanced commercial farmers in a very short time. The object of the scheme was to facilitate the development of commercial farming and rural prosperity by creating a nucleus of proficient peasant farmers who would, by their example, inspire others to improve their farming and seek their living from the land" (Kay 1965).

Trickle-down effect, demonstration effect, cash income, cash crops, creation of a middle class of peasants and identifying progress with mechanization were the main ideas. Another disastrous idea was the concept that there were no managerial requirements, that "primitive" agriculture of this kind was rather simple, that its labour requirements outside the family were low and its capital requirement very low — it was enough just to offer land. The absence of machinery made agriculturalists underestimate the capital requirements of peasant farming. Sophisticated small farming and irrigation needs rather large amounts of working capital.

When most of such schemes misfired and were discontinued, this was blamed on the stupidity of the farmers who did not want to become progressive. The irrigation schemes succeeded better, because of the total institution character of such schemes in Africa. This was also taken as proof that African peasants had to be regimented. The idea of the peasant as a clod, who does not understand his own best, permeates colonial and independent government (Moris 1967, Chakela 1973, Lazaro *et al.* 1977, Boesen 1977). But not only is he an incompetent clod, he is also lazy and does not want to follow government instructions (Barnett 1977). It may seem easier to describe a solution for a situation where tenants and cultivators are said to be lazy: more regimentation, more work, more recommendations. Several conflicts arise from this, one being precisely the conflict between prescriptions based on the concept of the peasant as a lazy clod and the probably more realistic opinion that administrative and extension problems have to be solved.

But the main conflict between farmers and government is the peasants' refusal to accept recommendations and regimentation and recommendations based on the "latest scientific knowledge" (which in the case of East Africa and the Sudan meant that it

is from the 1950s).' Peasants refuse and this creates an instant conflict between the cultivator, who knows his environment and who knows how to manipulate it, and the government extension, who does not understand that the peasant lives by his wits and not by his hands alone.

Information is, of course, essential to the farmer, in irrigation farming as well as other types of farming. Good information transforms a farmer's choices from guesses to a gamble, to a taking of calculated risks. Illiteracy had no real impact here one way or the other. (Folk wisdom is usually large and practical instruction and experience is as important as being able to read instructions on a fertilizer sack (White 1977.)

The peasant who knows enough to anticipate his yields under varying conditions has a power to transform uncertainties to risks. He is the one who knows how to live with the inadequacies of water supply in Pakistan and India or the Gezira; he is the one who can demand a better service. But he needs correct advice. Agricultural staff pass on recommendations, not information.

What kind of information — in the name of recommendations — do they get?

In the Gezira scheme, water distribution is according to the "average principle". This means that the "average" farmer gets an average amount of water for an "average" crop over the year. Everybody gets water over the year, but not necessarily at the precise or necessary moments. This concept is closely related to the idea of "normal rainfall" and other peculiarities in the "folklore of the normal" that simplifies administrative thought.

Administrative assumptions of this kind are never based on sound knowledge. In the *Handbook of New Personnel* from 1951 for the Gezira (which, however, is still in force), one can read:

> "52. Before any irrigation is embarked upon, a number of particulars must be ascertained beforehand. Having decided it is possible to grow certain types of crop, the volume of water required to bring these crops to maturity must be determined with due regard to all circumstances; this is known as the water duty ... It may be that the precise water duty in the Gezira is not yet unanimously agreed upon, but an over-all figure of 30 cubic metres per *feddan* per day seems fairly safe for design purposes (of canals)."
>
> "53. Broadly speaking, the agriculturalists have found that a volume of 400 cubic metres of water is required in the Gezira on each *feddan* of cotton every month during the dry season. Also that, on average each *feddan* of cotton should be watered every 15 days. Though this applies primarily to cotton, it suffices for other crops such as *dura* and *lubia*."

As Barnett (1977) points out, the operative sentences are "for design purposes" and "Broadly speaking ...". No one obviously knows anything about the known behaviour of cotton and if they do, it is not put at the service of the cultivators. Irrigation technicalities, rather than agricultural realities, seem to determine decisions about watering.

The tenants have solved some of the problems, but created other conflict-generating problems instead. The tenant is supposed to water his cotton plot, which is divided into fourteen sections. They are supposed to be watered section by section and three or four days of watering every two weeks are supposed to be enough for the whole plot.

This system is calculated on an unreliable flow of water and, in reality, the average number of days that the farmer has to tend his cotton is more likely to be seven. As the cultivator also grows other crops than cotton which need attention, it is difficult for him to use seven days out of fourteen only to look after the water flow, the earth bunds etc. So tenants have devised a new system, which has been called the "open" system or the "grid" system. This means that they water the whole plot at the same time. Earth bunds are still important to prevent uncontrolled flooding, but this method is an unofficial modification. It is obviously efficient and as good as comparable techniques (Barnett 1977, Farbrother 1970, 1974). The method has much less labour input, but it leads to two problems that we shall come back to: the relations between tenants and the administration, especially the low-level administration, and the conflicts between tenants during times of water shortage.

(b) The pilot project syndrome

Robert Wade has given a good description of a conflict-creating situation in a paper on the Indian Command Area Programme (CAP) (Wade 1975a), which illustrates the problem of redistribution through administrative channels and the problem of improving the situation of the poor without obviously discriminating against the rich. He assumes no revolutionary changes, but describes the result of the so-called *kota* method (named after a city in Rajasthan, where it was at first introduced). The idea was to realign and reorganise ownership structures, consolidating land, thereby realigning boundaries as well as interfering with the topography. The idea was supported by the IBRD and, as Wade says, "India is the Bank's biggest customer and the biggest single use of Bank resources in India is for irrigation and command area development". Central planners and influential people at central government level, "notably planners and engineers with an authoritarian frame of mind", endorsed the programme, which has a second weakness which it shares with many development programmes in the world — the submission to the "pilot project syndrome". Solutions to problems are devised on a small scale without regard to problems of replicability on a larger scale.

Wade shows how the various components of the *kota* "package" are interrelated and also their respective disadvantages. Boundary realignment and land consolidation is one such conflict-generating component. It is essential to the *kota* system and will drastically reduce the length of water courses and drains, and, therefore, also maintenance costs. However, land consolidation implies a full cadastral reconstruction. Records are out of date, if they exist at all, and the administrative work of reconstruction is, of course, enormous and perhaps even impossible, bearing in mind the general level of administrative efficiency. Cultivators tend to be attached to the piece of land they have, especially if they have worked for a generation or two improving the soil, putting in wells or trees. These were common problems in the process of land consolidation in Sweden during the last century, as were indeed conflicts other than those over getting a consolidated, but maybe less fertile, piece of land: tenants were evicted, and wealthier cultivators with large unregistered, and thus "taxfree", holdings were forced to give up some of their land. Conflict over holdings and title disputes will be a lengthy process.

It may be added that the problems of traditional inheritance of land and land consolidation are not well understood.

(c) Fragmentation vs. indivisible technology

Edwards and Biggs (1978) have shown how a government can create a situation of conflict without really trying. In Bangladesh, the fundamental contradiction is between small and fragmented landholdings and a high level of mechanization, which in turn requires a high level of cooperation. In this conflict between

fragmentation and the indivisible technology of mechanized irrigation, government has tried to introduce village-level credit cooperatives, which, however, only reflect existing power structures rather than introducing a land consolidating scheme. The main part of government subsidies goes to large-capacity irrigation methods, in spite of the fact that Mostis (Manually Operated Shallow Tubewells for Irrigation) have spread (Islam 1976, cf. also Clay 1975).

(d) Government and irrigation and nomads

When a government decides to implement an irrigation scheme or any agricultural scheme for that matter in arid lands, there is usually a group of livestock peoples which has to move either to further marginal lands or to town.

In Sudan, the Shukriya Arabs of the Butana plains were the victims of an expansion of mechanized farming of millet and sesame. The Khasm el Girba scheme irrigation was offered as a solution to the homeless Nubians from Wadi Halfa and the Second Cataract whose land had been drowned by the high dam. This scheme turned important pastoral lands into fields of wheat and cotton. The Ethiopian government, with the aid of several transnational companies, turned the Awash valley pastoral lands into sugar cane and cotton (Dafalla 1975, Sörbö 1975, Bondestam 1974).

This may sound like a beneficial type of development, but irrigation on marginal lands is much dependent on regularity, discipline, and various inputs, such as fertilizers. When this does not work, there is a very heavy negative environmental impact. The only peoples who can really use marginal lands profitably are the livestock peoples; and, besides the humanitarian aspect of chasing people away from their livelihood, there are many questions concerning the wisdom of turning these lands into some kind of agriculture.

The Bisanadi area between Meru and Isiolo in Kenya used to be exploited by the Watta (a sub-group of the Borana) and provided a drought resource for their cattle-owning patrons, the Borana Gutu. Today, the Bisanadi area is a national park and a game reserve and the herders have become irrigation farmers, as their traditional form of subsistence is illegal. The cattle people have to find other pastures during drought (Dahl and Hjort 1979).

(e) Planning of water supplies

The planning and execution of water supplies in rural areas has been supported by the Scandinavian governments for over 15 years, mainly in East Africa, Tunisia and Bangladesh. The expression "provision of water supplies" is really not wholly correct, as there are always water supplies. What is meant is the installation of improved water supplies.

Problems of such undertakings have already been discussed. At present, we want to discuss potential conflicts generated by the problems discussed earlier. Widstrand has described a common situation in an East African village (SIDA 1977):

> "It is a new and hot, shimmering day. Nothing much happens in the village; there is a smell of stale beer and dust. Suddenly on the road large dust clouds: a procession of Landrovers approaches the village. Out of the vehicles spill a crowd of county councillors, district officers, local politicians, and sweaty, but competent, experts. Someone gives a speech, telling the villagers that now development has at last caught up with them and they shall have water, the toil of women shall finish and health, economy and what-not shall sprout. Competent technicians unpack the

> machines and a day of infernal noise begins. The surprised laity invite their guests to a meal of beer and goat meat, more speeches, departure of the caravan, but for some experts, who in a few days time produce water out of a pump. They depart: 'Here is your water, look after the installation and phone us if something goes wrong.' Phone! After some time the diesel runs out, the pump disintegrates, and everything is as before. After all, no one really liked that clear cold water which hurt their teeth. Water should be brown, muddy, tasty and more filling. And, by the way, during the rainy season it is much closer to go to the river than to the pump."

This description is probably not totally fair, but is largely true. It shows two things: that in most cases the local population is not involved in the planning of their water supplies and that there has been no effort to integrate the arrival of water into a system of discussions, training, and information on the importance of water for public health.

Conflicts always arise out of situations where people have no say in the planning of situations which concern their basic needs, to use a trendy catchword. As long as water supplies are centrally planned (which is easier: people are not in your way) and as long as donors believe that local administrations really know what they are doing, conflicts will be there. The central planning situation is also easier for the donor, who produces a package, a technological fix, to be used at the discretion of the receiving country.

District administrators do not like to see installations vandalised; and this may prevent other development activities in the village. If there is a charge for the water, conflict is ripe. Who wants to pay for water? It comes from God; we provided the labour; and did not the DO say that the Swedish government provided the pipes and taps? Another type of conflict arises when people in the village think that the investment in water could have been used for some other purpose in the village. What is supplied is at variance with the perceptions of the local community and the choice they would have preferred, if given the option. In many cases, villages have a drinking well (Burton 1974, Bradley 1974) or a protected source and do not really need another water supply. Maybe the money would have been better used for improvement of the existing supply, and the training of someone to look after a pump, a concrete well-top or some such thing; villagers are in many cases fairly well aware of their needs.

A solution to this sizeable problem is not easy. Donors are now well aware of difficulties of this kind and so also, are increasingly, governments. Simple cooperative arrangements around a utility of a simple type (where the usefulness is known to, and felt by, the local population, which then also has, and feels, a responsibility for the upkeep of the installation) seems to be one solution. Examples can be seen, in very successful rural village installations in the Kenyan Central Province, where, again, the conflict has not been concerned with the usefulness of water, but is rather conflict between local people who all want to have private installations, or between local authorities and the water department over the capacity of the installations.

(2) Conflicts in Water Administration

One major cause of conflict in irrigation is the often occurring periods of water scarcity in the field. These may depend on climatic fluctuations, but most often on administrative practices.

The restriction of water supplies in time or in place is sometimes necessary. Other forms of control include restriction on certain types of crops, size of holdings under one type of crop, or other limitations on the demand of water.

(a) Water restrictions

Differences in irrigation practices in India provide an example. There are four main types of restrictions.

(1) The canal irrigation areas in the northwestern part of India are fed by perennial rivers; the cultivator knows (but for the whims of an erratic and fossilized water administration system) what he is legally entitled to; and he chooses his crops accordingly. Conflict-generating situations here concern, as we have said, administrative practices and the different access to water due to ability to manipulate the administration.

(2) In Gujerat, Maharashtra and Madhya Pradesh, we meet a much more deliberate government-controlled system, this time not only controlling water, but also the crops. The reason for this is, of course, that the rivers are not abundant and the irrigation water depends on the monsoon. The "ideal" type of this system is based on an agreement between the cultivator and the government on what kinds of crops he intends to grow and irrigate. The State Irrigation Department then gives him permission, usually for a six-year period, to grow such and such a crop on such and such an area (Government of Maharashtra 1962, Khursala and Ghandi 1969). Other factors which influence the decisions of the Irrigation Department concern the edaphic components, projected rainfall, topography, soils etc. This means that areas under irrigation are not continuous, but mixed with land under some system of rain-fed agriculture.

Conflicts arise between people with and without irrigation agreements; and the whole exercise is, of course, a kind of "ideal" situation — again a conflict between plan and reality. Unauthorized irrigation plus, probably, overwatering in the upper parts of a river or under a dam, leaves cultivators at the tail-end without water, in spite of their agreements. Levies and fines are difficult to administer and ridiculously low.

(3) In other Indian states, like Andhra Pradesh, Karnataka, and Tamil Nadu, controls are exercised according to what may be called a "duty method". Duty is an important irrigation concept in India, and defines the area in acres that will be satisfactorily watered in a normal year, if there is a continuous flow of one cubic foot per second during the growth period.

"Satisfactorily" and "normal" are, as we have discussed above, concepts from the peculiar unrefined vocabulary of irrigation agriculture. A difference is also usually drawn between the *rabi* and the *kharif* crops, or rather between wet and dry (the *terminus technicus* is Irrigated Dry). Wet crops are sugar and paddy rice; dry crops are crops like wheat, peanuts, and maybe also cotton, which only require additional irrigation.

The Irrigation Department divides the agricultural land into land to be used for wet crops and land to be used for dry crops. For the cultivator, this means that if his acreage is in the "wet area", he has no other choice than to grow paddy. The "duty method", in this way, makes the administrative complexities much easier; but the system is, of course, not free from conflict of the same types as those described for other control systems: the unauthorized use of water in the upper part of the system leads to scarcity of water at the tail-end.

(4) Some areas in Southern India — in Tamil Nadu and Kerala — have rivers which, even if they dry up during parts of the year, have enough monsoon capacity to serve irrigated agriculture. Therefore, no rigid controls are necessary (Wade 1978).

(b) Communal labour

Management control over crops creates conflicts between cultivators and between cultivators and officials. Resentment against communal labour acts in very much the same way. Conflict in farmers' associations will be treated below, here we shall discuss some aspects of conflict over communal labour.

Much irrigation work, and indeed rural water supplies, involve communal labour. This, incidentally, is often mistaken for public participation. Such participation is indeed something more than the mere provision of manual labour. This is evident from the studies of irrigation conditions in Pakistan by M. Lowdermilk *et al.* in a long and important series of contributions from Colorado State University. They discuss social and organizational points of view at length (Lowdermilk *et al.* 1977), some of which have already been mentioned. Water-management improvement programmes on some of the water courses analysed by Lowdermilk *et al.* showed that the more the conflicts were associated with such management improvement programmes, the greater the tendency for reinforcement of existing social and economic cleavages, and the less the propensity of farmers to get organized.

(c) Sanctions

The unauthorized use of water in irrigation society is bound to create conflict between participants in the system. It is, therefore, necessary for the government or the administration to have a system of sanctions at its disposal to punish and prevent misuse. Barnett (1977) has shown that such systems do not work very well in the Gezira and identifies the problem with the relationship of the tenant as an individual with the Gezira Board, instead of belonging to a cooperative, thus leading to a lack of social control (see also Founou-Tchuigoua 1974). As long as the cotton gets enough water, the field inspectors do not bother to report unauthorized use of water for the growing of other crops.

A potential conflict area is the limited legal resources of the Department of Irrigation in the Indian and Pakistani system. The Canal and Drainage Act of 1873 which is still the basic piece of irrigation legislation in Pakistan, makes it impossible for the Irrigation Department to interfere below the *mogha*, except in a very limited number of matters. Thus, any infringement of the rules by farmers is controlled by other means or not at all. Government intervention has been limited to settlement of gross violations.

Wade describes a similar situation from Andhra Pradesh (1976) and says that administrative rationing without penalties or enforcement of the administration's ideas are meaningless. Like the Pakistan example, the Irrigation Department has not the responsibility for the enforcement of current legislation in this field; that rests with the Revenue Department and the police. Concealment of land under irrigation is also prevalent by agreement with low-level Revenue Department officials. Fines levied, if one ever gets that far, are ridiculously low, such as twice the water rate. Penalties are waived for one reason or another. The amount of endless legal disputes can only be imagined.

(d) "Corruption"

We have already mentioned several times the foremost problem in irrigated agriculture: the unreliability of water supplies (this incidentally, seems to be a major problem also in rural water supplies, but creates other conflicts). It is, therefore, almost natural, or at least understandable, that a cultivator tries to influence the person who can produce water (as extra water, unauthorised water, water at special times, or at special places). Irrigation staff are, therefore, subject to strong pressures, threats, and inducements. This leads to what we, in our calvinistic approach to life, call corrupt practices.

But this creates conflicts between cultivators; and if irrigation management is to be improved, irrigation officials at the low level will have to behave in ways which will be very unpopular with some people — especially the more influential people at the top end, who tend to get the water at the cost of the tail-enders (Chambers 1978). There is no easy solution to this "soft state" problem, as governments affected by the "average-normal-over-all efficiency" syndrome also do not really care whether water is used at the top end rather than at the tail end, as long as production figures for a command area or schemes are not deteriorating. Social justice has a difficult time in irrigation, as elsewhere.

The administration of irrigation systems should decide how social benefits are distributed. If the administration does not succeed in this, water becomes a decisive factor in the distribution of economic and political power (Jacoby 1976).

Some examples may serve to illustrate that corruption is fairly common and, indeed, is sometimes so necessary for survival that it is an accepted part of life.

The gate keeper may be persuaded to open the gate to let more water through (Barnett 1977); the gauge reader may under-report the amount of water taken; the overseer may instal larger watercourse outlets (Wade 1975a). The assessors (*patwaris*) in the Pakistani system assess each farmer twice a year for each crop. They are supposed to reduce the possibility of corruption, but as the assessment procedures and the water rates to be paid are so mysterious, the person who cannot fill in the right forms or does not know his rights is very much in the hands of the *patwari*.

> "With the Patwari is a record of every plot of land within the revenue area ... what is grown on it, the names of its holders, and their individual rights in it. He enters in his volumes any changes brought about by death, with a statement of the rights of each heir. He notes transfers of holdings and any alterations in legal rights. Also he keeps a record of all rents paid to each landlord, and arrears. He must appear in court to give evidence in all cases dealing with land rights in his area. If more of our farmers could read, and if each of them would keep his own authorized copy of the record of his holdings made out by the Settlement Officer every thirty years, along with legal records of current transactions, our accountant (*Patwari*) would serve as an inoffensive employer. But as long as they do not do this and depend entirely on his annual recordings of their rights, they vest him with powers which he, a low-grade agent, could hardly be expected to disregard" (Wiser and Wiser 1965).

Tubewell operators create "accidents" which have to be fixed. It is also important to be aware of the difficulties to control less qualified subordinate officials and the fact that there are few sanctions against them. Reports "may not be particularly important for a man who has little hope of advancement anyway" (Reidinger 1971). Appeal procedures are cumbersome and expensive for the farmers.

The main problem here is the position and expectations of the low-level personnel of which we know very little. Farmers in the Punjabi group analysed by Mirza (1975) consider "fairness" in dealings with an official to be a favour in itself. The influence of large landowners on water services and the political importance of water makes studies in the administrative practices of irrigation systems urgently necessary (Bottrall 1978). Such a study must not only emphasize social inequity and uneven distribution of resources, but must lead to an understanding of the many different types of problems and suggest lines of action for changes in administrative routines to the benefit of irrigators and the efficiency in general of irrigation systems (Clay 1976).

CONFLICT BETWEEN FARMERS

(1) Rich and Poor Farmers

The conditions discussed in the previous section are, of course, important also in this connection. The mechanisms of government set up to manage peasants create conflicts between peasants over scarce water resources and tend to increase social and economic inequality. It is an increasingly recognized fact that the introduction of any technical improvement immediately widens the gap between rich and poor, whether it is in water supplies, tubewells or irrigation credits. There are many reasons for this, but, before we look into some of them, it is important to emphasize that the simple dichotomies such as between rich and poor or low-potential and high-potential areas are too simplified for an accurate description of the relations of production.

In all areas, rich or poor, with high or low potential, there are microstrata of inequality: poorest, poor, less poor and not-so-poor (Padfield 1970). To a certain extent, this reflects competence (there are bad irrigation farmers, terrible livestock herders, and outright incompetent cultivators); but that is only part of the explanation. Implicit in such a definition of strata is that benefits will be used accordingly.

Benefits of a given input will be captured unequally, frequently increasing the differentials in income which already exist (Jacobsen *et al.* 1971). Less progressive farmers, with their lesser water needs, must subsidize more progressive farmers, with their greater water needs (Jacobsen 1972). Or, as in many cases if farmers as usual suffer from an unpredictable water supply, they try to calculate the risks and use other tactics to evade total catastrophe. This means a lowered maximum output of the farmer with difficult access to water. As Wade (1975a) points out, farmers who have a predictable water supply can grow HYV, and part of the inequality in deliveries of water is due to a lower seepage rate on large farms.

Wade (*loc. cit.*) discusses some factors which tend to blur the dichotomy rich/poor, big/small. One is fragmentation of land, another is rivalry between faction leaders for followers, which tends to offset tendencies towards more unequal distribution. There are also cases, where the uncertainty of water supplies encourages cooperation (Harriss 1976), such as in the traditional systems of water tank allocation in small tank villages in Sri Lanka (Leach 1961). Where big and small farmers depend on the same watercourse small farmers may ask big farmers to intervene on their behalf to secure a better water supply.

Another interesting question is raised by John and Barbara Harriss in connection with Robert Chambers' statement that "the poor are screwed down seasonally into subordinate and dependent relationships in which they are peculiarly vulnerable to exploitation" (Chambers 1978a). Seasonality and its *sequelae*, in the context of irrigated agriculture, is not well understood. If agriculture is less dependent on seasonal fluctuations, there should ideally be less patron-client relationships or vertical dependency relations. Rather, the intensity of rural protest or "horizontal political mobilization" should strengthen the economic power of poor groups. The Harrisses mention the example from Tamil Nadu (from Frankel 1971) where landless labourers have been provoked to protest in areas of most assured irrigation (J. and B. Harriss 1978). However, patron-client relationships are certainly in evidence, as has been mentioned above. In the North Arcot District in Tamil Nadu, the private ownership of electric pumps gives some sections of society a control over the environment (Chambers and Harriss 1977, cf. J. and B. Harriss 1978 for further examples, not directly connected with irrigated agriculture, also Barnett 1978 on the scheme in Sudan, Ströberg 1977 on Bangladesh).

It is difficult to find precise evidence on the actual distribution of benefits (Wade 1975a, Thorner 1962, Reidinger 1971). But the important factor is probably that of ownership of land. This is an important determinant of power, as leadership, power, and influence are all highly and significantly correlated with size of landholding (Lowdermilk *et al.* 1977). It is important in this connection, primarily as a means of access to water (Thorner 1962, Djurfeldt and Lindberg 1975, Wade 1975a). Big and influential landowners get water first, and have a secure access to water either through organizational connections or political pressures (Wade 1975a, Whitcombe 1972, Schaffer and Huang Wen-Hsien 1975, Lazaro *et al.* 1977). The relation to land forms the basis of the relations of production and is, of course, the major conflict-creating issue (cf. Djurfeldt and Lindberg for a marxist interpretation).

In Botswana, many boreholes which were formerly public property have been sold to syndicates and private persons and this has radically reduced the potential availability of grazing land to other users. The net effect has been to provide cheaper water to fewer, better-off people, while squeezing out some of those with smaller herds, forcing them to move to the already overgrazed areas around communal water points. Land adjudication proposals have provided new opportunities and incentives for the richer man to become more prosperous; and land-use planning all too often displaces, rather than absorbs, population. Those already well established obtain exclusive rights to resources which previously contributed to the support of others (Chambers and Feldman 1973).

The two systems of allocating water to farmers in canal systems in Pakistan and in North West India are *kacha warabundi* (*warabundi*, Urdu, means agreement). It is a system of rotation agreed upon between the farmers. Small farmers are vulnerable to manipulations on the part of the larger farmer and tend to be in favour of the other system, *pacca warabundi*, where each turn is fixed by the Irrigation Department. This system protects farmers' rights, but the flexibility of allocation is lost, as water trading becomes illegal. Combined with other fossilized practices, it is, however, a method which might increase inequality in water allocation (Mirza *et al.* 1975).

According to Mirza (1975), water disputes arise under the *kacha warabundi* system in two ways. A farmer considers his "turn" to be inadequate and takes additional time; this can be done by slow or fast watches. Secondly, large landholders may try to settle their disputes by increasing their share of water to the detriment of the smaller farmers. Such farmers, therefore, petitioned for a switch to *pacca warabundi*, but with the pre-arranged mutual consensus of their larger neighbours. Such a shift takes place faster on watercourses where there are many factions and many conflicts.

Cairncross *et al.* (1980) argue that the benefits of self-help in rural drinking water supply schemes are likely to be achieved only at the cost of not achieving an optimally fair distribution of resources among a population, precisely because the best-organized and wealthiest sections of a population will respond first to initiatives to organize such supplies.

(2) Conflicts in Farmers' Organizations

Cooperative efforts, farmers' associations, and groupings on the basis of brotherhood, caste, or family succeed in many cases, especially if they have a clearly recognizable utility to protect or cooperate about. But such associations can also be the arenas of deep-seated conflicts. Such conflicts have been described by Lowdermilk *et al.* (1975) from the Punjab. A main conflict is always about land; and, as access to land means access to water, this is important in this context. Another area of conflict concerns collective action to clean

watercourses, where dissatisfaction with what was achieved increased towards the end of the canal system. However, people at the tail end are more likely to support collective leadership arrangements in villages than those towards the head.

(3) The Quarrel Parameter

J. Briscoe *et al.* (1978) have looked at the domestic water use in a village in Bangladesh and the water patterns and the selection of different kinds of water for different purposes. The choice of drinking water is affected by distance to the source and organoleptic factors, such as odour and taste. The parameters chosen also include quarrels at the source; and, together with distance, these constitute one of the most powerful determinants for the poor section of their sample, but not for the rich. The reason for this is that the rich obviously either have their own tank or tubewell, whereas the poor either have a share in one tank or have none.

DONOR AGENCIES AND GOVERNMENTS/LOCAL GROUPS

(1) Expatriate Expertise

The relation between donor agencies or governments and the receiving countries has been the topic for a substantial and controversial body of written works since 1949.

The United Nations Plan for an expanded technical cooperative programme, *Technical Assistance for Economic Development*, from May 1949, states, for example:

> "The techniques recommended to underdeveloped countries under an international technical assistance programme must be fully proven and practical ones and suitable for use in the particular recipient country. Otherwise there is a danger that underdeveloped countries may be saddled with unsuitable facilities and unworkable methods at a stage when they still lack the knowledge necessary to perfect or replace them".

This is not the place for a history of technical cooperation. One must, however, emphasise that historical precedent has played an enormous role in all development work, from the crude idea that development means "bringing up developing countries to our standard", to adherence to local models like, for example, the North West Indian irrigation systems. In the water field, an almost superstitious belief in the efficacy of modern technology, plus the concept that water development appropriately is in the domain of the engineer, explains the technocratic approach to identification of problems in rural areas: more and better technology and education of the "natives" to understand the benefits of such technology. The causes of underdevelopment are thus sought in a narrow circle and along a short route of cause and effects. The technocratic approach leads to a listing of imperfections which need to be corrected — one deals with symptoms, rather than causes. This approach, which is partial, almost always reflects a disinclination to deal with social factors and — more important — with political realities. This lack of multi-dimensional analysis and the lack of recognition that problems are interdependent, have a long history which has led to many suboptimal solutions. For example:

(a) Already in 1959, UNICEF/WHO studies strongly advocated community involvement for the implementation of water supply and sanitation programmes (UNICEF 1978). It is quite clear that recommendations to this effect have had no impact, because of little government receptivity to such proposals (Widstrand 1979).

(b) In Pakistan, the need for additional data was felt by foreign experts. Such experts have been mainly interested in applying sophisticated techniques such as mathematical modelling and operations research methods to fill gaps in available information. Water development plans made from such "home-brewed" data have been unsuited to local conditions and have not brought projected benefits, which they probably would have in the United States, for example (Bokhari 1977).

The 1970s have seen a change in this tendency; and we think it is only fair to mention that the governments of small countries, like the Scandinavian countries or the Netherlands, have clearly recognized this problem of analysis and have tried to introduce changes in the approach both in the UN system and in bilateral agreements.

One conflict-creating problem, however, is that most senior people in the water field are either foreign experts or members of the local elites with their educational experience from Europe or North America. New ideas of analysis and new approaches, including discussions on equity, social effects, and political constraints in the analysis, have been strongly resented and termed interference. Climatic bias in education, promotion patterns stressing seniority rather than competence — thus not creating incentive for further education — and shear political myopia have contributed to the refusal to discuss water development in terms of equity problems, such as differential access to water and sanitation facilities and the impact on health of such differences. Other contributory problems involve questions of pricing and inequality, ownership of land and water, changes in such owner systems, and local participation in decision-making.

Such a conflict, again a conflict over visions, between a more "progressive" donor country and a "conservative" recipient has caused problems and accusations of interference (Ströberg 1977). One way out for the donor country is, of course, to fall back on historical precedence, and to analyse and conceive rural water problems in terms of what the donors can offer by way of technical expertise and financial resources. A solution for the recipient country is to redirect their requests to another donor country, less interested in equity, but more in projects which absorb substantial financial resources.

A drastic example of differences in opinion between donor and recipient is the adventures in drinking-water exploration in Oman experienced by the FAO. Efforts to create a National Water Resources Centre above the immediate pressures of day-to-day politics became one resounding failure. There is in Oman an absolute shortage of water and a definite need for the efficient management of water resources and a national policy for water conservation. As, however, the advice of the expatriate experts conflicted with the vested interests of government ministries and the local elite (who were the owners of the diesel pumps used to provide water for swimming pools and garden watering) the experts were sent away and the project discontinued. Very poor people, concerned with survival today, may not be too concerned with the long-term prospects. In this example from Oman, described by John Townsend (1977), it is interesting to note that very rich people take the same attitude, not, of course, because of survival problems, but because their basic philosophy is fatalistic and the concern about tomorrow is regarded as a blasphemous intervention with the divine will.

A recent conflict, or at least a recently voiced disagreement, concerns the technical condition of rural water supplies some ten or more years after installation. Several *ex-post* evaluation surveys in East Africa (GOE 1976, ROK 1977) have pointed out that the engineering and construction of such works have not been up to standard. Many consultants have sold shoddy workmanship, second-rate material and third-rate engineering capacity which has led to pressure problems or capacity problems, because of wrongly estimated capacity needs in rural water supplies, to neglect of salinization and waterlogging, because of

neglected drainage in irrigation projects, and to selling of unnecessarily stupid technological solutions — witness the immense flora of pumps and latrines!

The dependence on the donor and his technological extention has sometimes been so great that recipient governments (for example, Afghanistan and Botswana) have not ventured to voice disagreement, as the contractor then would leave for other more lucrative ventures elsewhere. Many donors specify contractors to be used by the recipient country; and this has, of course, been the reason for many conflicts. In Botswana, U.K. contractors working out of Zambia have lacked effective management and supervision, and have had problems with the transfer of funds from Zambia. This, in turn, has led to work not being finished, because of delays in payment.

(2) Conflicts between Donors

There are many donors active in the water "racket". One major institution active in this field is the IBRD — the World Bank. As the Bank is also involved in many other development activities, its recommendations often carry undue weight with governments. Acceptance of an IBRD recommended action, often in terms of a prerequisite condition for a loan, may cause a conflict of opinion between the IBRD, the recipient country, and another donor active in the same field. A recent conflict of opinion over the pricing of water between the IBRD, a Scandinavian donor, and an East African government is a case in point.

With reference to the problems of financing the operation and maintenance of installations, the World Bank made it a condition for a major loan that an effective water tariff was introduced. Such a tariff structure would of course affect all water supply installations all over the country, regardless in which form the water was supplied. This would lead to a situation where the donor country would have to re-examine its present policy of free water at communal water points.

The donor country was not contacted during the discussions between the World Bank and the country representatives, but received unofficially the World Bank proposal: CWPs should be reduced to a minimum, free water should in principle not be available, and CWPs should be replaced by water kiosks. Such a policy would probably lead to a problem for the poorer sections of the population, who would revert to fetch their water from traditional (and unsafe) sources.

The country negotiated an agreement with the World Bank, based on some miscalculations about the real price of water (1 KShs per m^3 rather than 2.50 KShs per m^3), and ended up with a situation where people who buy their water by the *debe* (a twenty-litre petrol tin) paid about 250% more than those who had individual connections in their back yard. The $20 million loan was to cover 20% of the forthcoming water programme; other donors would contribute the remaining 80%.

The major donor country, which was never allowed to take part in conclusive discussions on the new tariff structure, began making noises about withdrawing their support, not only from the water sector but generally.

The country then produced the full documentation on the new tariff structure, and joint discussions between the country, the donor and the World Bank made it clear that the country wanted to re-negotiate its agreement with the Bank. The Bank hesitated, but after increased pressure from the donor and an amended tariff structure proposed by the country, the loan conditions were re-negotiated.

This case shows two things: a country may end up in a difficult situation if there are widely divergent philosophies among the donors. Furthermore, it shows that it is possible to solve a conflict in which one party stresses the financial returns of a water programme and the other stresses the social benefits.

CHAPTER 6

Education and Training

DIFFERENT LEVELS OF EDUCATIONAL EFFORT

A large part of the development effort is concerned with skills and the training procedures to attain such skills. Another area of concern is the general level of education of the public, which again is important when one discusses acceptance of new techniques and new ideas. A further problem is the applicability in developing countries of skills and technical knowledge acquired in another part of the world, the problem of "climatic bias" and the need for retraining.

One way of looking at the education problem is to divide the water interest groups into three categories: the donors, the producers — local authorities concerned with the production of installations, etc. — and the consumers. Each of these three groups have different educational needs and also different needs at different levels within each group.

In this section, we discuss some of the problems of education of professionals in the producer group (engineers and scientists) and some problems connected with the education of donor experts.

The educational needs of the consumers are discussed rather extensively in terms of hygiene and health education. There are, of course, other categories in all three groups which would need consideration, such as training of consumer pump attendants, of middle-level producer personnel, and of middle-level "peace-corps-type" of experts or volunteers (Report, IHP meeting on education, Uppsala, September 1979: see IHP (1979)).

(1) Training of Local Personnel

This is an area of concern which goes far beyond the scope of this volume. The training of middle-level personnel (foremen, draughtsmen, plumbers, pump assistants, repair mechanics, sluice attendants etc.) is a sadly neglected area. Only recently, have donor countries begun to introduce large-scale training activities in connection with water projects, basically in order to "protect" their investments. In many countries, the market demand for this type of personnel is great, and government employment is probably not the first choice. The market exercises a profound influence on another scarce resource: engineers of various backgrounds. They are badly needed in administration and planning offices, but are very hard to find. One reason for this is, of course, again, the brain drain away from

government service in countries where the private sector offers more attractive contracts. High-level manpower (not only engineers, but accountants, computer specialists etc.) has been discussed by numerous consultants and government working-groups in many countries. But — as a recent report from Kenya shows (ROK 1978c) — such documents are often too optimistic. The facts do not support the view that Kenya in the near future can take control of, and execute, its civil engineering programmes. The evidence rather suggests that the pool of engineers of all types is small and there are too many agencies competing for access to this pool.

The pool is not augmented by the university in an adequate fashion. This problem raises basic educational questions of importance far outside the water field, such as: If the university or a second university were to introduce new courses or increase their intake, is there then a supply of school leavers who are competent to use such opportunities? Is the mathematics teaching in schools of sufficient quality to ensure a number of able students to satisfy entry requirements? Or, is the expectation of self-sufficiency in engineering within 5-10 years a deluding myth in Kenya and in other countries in the same situation? If it is, then the fact is that the necessary expertise for implementing water programmes for many years to come has to be sought from expatriate engineers for one or two decades.

(2) Training of Expatriate Personnel

Such a situation dramatizes the need for a different or expanded education of expatriate engineers. We have talked about "climatic bias" in several places in this volume and climatic bias or the "temperate municipal" (Bradley 1978).

We train our hydrologists and water engineers to handle an environment with drastic temperature changes over the year, ample precipitation in the neighbourhood of 800 mm/year, and we train them to handle this with a minimum of personnel and a maximum (not optimum) of gadgets and complicated automated machinery and sophisticated electronics. We have our own work attitudes, our own political and social set-up, our own way of doing things and thinking about things, and above all our own culture that we cannot get away from.

We give these people some additional training in the form of a three-week course and send them out into a world, which, incidentally, does not have 800 mm/year (or, if it has, those 800 mm come in two days), which has no understanding of gadgets and electronics, which behaves completely differently, and which has completely different needs from ours (Widstrand 1978a).

There are many things that we take for granted, subconsciously and unconsciously: for example, the problem of data. We are used to regarding data in our own familiar surroundings with some suspicion, or we are at least aware of the validity of the methods used to collect them. We can also, from our training and experience, make idealized assumptions to fill the gaps in the available information. In developing countries, data come in two categories: the unnecessary and the unreliable; and they are extremely dangerous to base assumptions on (Bokhari 1977). For example, major irrigation field studies by well-known foreign firms in Pakistan made no measurements of farm-conveyance and field-application efficiencies, but assumed these to be 90 per cent and 70 per cent (World Bank 1976). These assumptions were used for eleven years in twelve major reports and several computer simulations for planning and development purposes and essentially took the focus away from farm-level problems (Lowdermilk *et al.* 1977).

Another example: our toilet training and behaviour is embossed upon our minds when we are very young. The water toilet is essential to that early and important learning process. During the past years, everyone, except some very few early compost enthusiasts, has recommended (almost unconsciously) sanitation systems with water-carried sewage, cess-pools, septic tanks and sewers. A system which uses 13,000 gallons of treated water to flush 165 gallons of human bodily wastes per person and year is obviously not the best in situations of water deficit and a lack of sewage treatment plants. Experts are astonished, when water toilets in Ethiopian hospitals get clogged by stones. If you recommend water and flush toilets, without knowing anything about anal cleansing behaviour — for example, the use of stone instead of toilet paper — you have fallen deeply into the cultural bias trap.

Thirdly: In the quest for sophisticated technologies, on the grounds that nothing but the best will do, the engineering profession sometimes produces a solution which is technologically advanced, often enormous, and with enormous costs like that of high dams and usually quite irrelevant to the needs of the country. After servicing the loans, there is usually very little money for the O and M function. A current slogan in the development literature is, "Small is beautiful". There is certainly something to think about in that statement. Small does not necessarily mean unsophisticated; thinking small does not mean thinking naively or primitively. The social profit is obvious (Vittachi 1978).

HEALTH PROPAGANDA AND INFORMATION

A third aspect of education concerns the types of propaganda or information effort which are necessary in connection with new installations of water or sanitation facilities.

The health aspect is here probably the most important; and in this section we disregard agricultural extension and different types of vocational training. The connection between improved water supplies and health is not well understood, nor is the connection between sanitation and health.

It is a set of problems intimately connected with the now popular, but very imprecise, ideas about public participation and user-choice alternatives. This in turn has to do with traditional and emerging local institutions which exist and which can be mobilized.

It is useful at this point to summarize some of the points of view of the relation between health and water, in order to assess the implications of water/sanitation schemes and irrigation projects on health.

A useful classification of water-related diseases has been conceived by David Bradley and elaborated by Richard Feachem (Feachem 1977, Cairncross *et al.* 1979). It is summarized in Table 6:1.

Bradley has discussed a further extension of this system which has implications for the types of water or sanitation installations necessary (Bradley 1978, Bradley and Feachem 1978). He introduces two aspects which determine the nature of excretal transmission: latency and persistence. Infections by the faecal-oral route are usually by infective agents which have no latency, i.e. they are immediately infectious, and have short persistence, i.e. they have a short survival time in the environment. Most viral and bacterial infections belong to this category.

TABLE 6:1

Category	Transfer mechanism	Example	Preventive measures
Water-borne	through water supplies	typhoid cholera infective hepatitis	improve water quality prevent casual use of unprotected sources
Water-washed	due to lack of personal hygiene	scabies trachoma bacillary dysentery diarrhoea	improve water quantity improve water accessibility improve personal hygiene
Water-based	through an aquatic invertebrate animal	schistosomiasis guinea worm	decrease need for water contact control snail populations improve water quality
Water-related insect vector	spread by insects that depend on water	sleeping sickness yellow fever malaria	destroy breeding sites of insect decrease need to visit breeding sites

To prevent such diseases, water is necessary for hygiene and hygiene practices must improve. Infective agents with short latency and long persistence (such as *Enterobius vermiaelavis*) are most appropriately dealt with by improved latrine installations and the hygienic upkeep and use of such installations. Agents with long latency and long persistence, i.e. agents like the eggs of hookworm, which need some time in a humid and rather specific soil environment must be prevented, not only by the use of latrines, but also by composting and an appropriate choice of the final disposal of faeces.

If we summarize the preconditions for a health impact of improved water supplies, it may look something like this:

- Safe water supply is a necessary condition for health, but it is by no means a sufficient condition.
- New (safe, improved) water supplies must be used, instead of the old, throughout the year.
- Water-use patterns must change to take advantage of improved quality and quantity.
- Other health measures and hygienic practices are necessary, as well as an improved primary health care system.
- Latrines must not only be provided; they must be used.
- New water supply or a water project must not create health hazards.

It is interesting to speculate what kind of educational or propaganda effort is needed, or feasible, to achieve a more optimal use of water for hygienic purposes.

It is important to stress that the concept *education* is used in a variety of ways. Very often, we hear that "education" will now solve the problems of underused installations; people will have to be "educated". This point of view has its base in a concept of rural people as uneducated ignoramuses, who do not know what they are doing.

The general idea that illness is due to "bad" education, and consequently that "good" education will prevent or correct illness, rests on a series of hopeful misconceptions. A health education programme *could probably be* the most cost effective means of reducing water-associated diseases, but there is little evidence to substantiate that it is so. Any local culture provides education; rural people know very well what they are doing.

It is very important to remember that most people, even rural people, have very definite ideas about water and choices of different types of water for different purposes, such as drinking, washing, irrigation. They have, in many instances, well informed opinions on safe water and of different types of water supplies. (It is also quite possible that whatever educational measures we suggest, they will involve more work for everybody.)

However, the cultural residues in disease perception are difficult and not easily changed for germ theory or some modern scientific explanation.

A wide variety of evidence exists to show that there is a lack of understanding of health and water-related diseases in many communities. Often, communities consider that diarrhoeal diseases are not communicated through food, milk and water or contaminated by excreta. Consequently, no attempts are made to take correct protective measures or to restore fluids lost through diarrhoea. Often, there is lack of knowledge that polluted water contributes to disease, as exampled by the State of Rajasthan, where at least 85 per cent of those served with improved water did not feel that there was any relationship between drinking-water and diseases.

In the Philippines, the main hindrance to the Department of Health's latrine programme is reported to be the people's reluctance to accept changes in living habits and the attitude that sanitation is the least of their problems. In many parts of Bangladesh, children are primarily given surface water to drink, rather than better quality tubewell water, because of the belief that tubewell water causes chills. Children are also unlikely to be instructed or supervised concerning the choice of container. As 25 per cent of children die before the age of five years in Bangladesh, water and sanitation education should primarily be focused on the mothers and children (UNICEF 1979).

We have only a few examples of educational programmes specifically related to this kind of problems of water and sanitation improvement:

- The Banki water supply in India had its educational activities generated from a general dissatisfaction with current conditions. Arguments were of a common-sense type, had relevance to people's daily activities, and information was correct (most important!) (Misra 1975, UNICEF 1979). Cf. also the SIDA programme in Tunisia (SIDA 1979).
- Sanitation programmes and water programmes in Paraguay are strongly community oriented and this fact has obviously played a decisive role in creating a need for a water education programme (Cardenas 1978, UNICEF 1979).

Success stories are, however, very few; and usually education programmes come down from above. One of the reasons for this is that the public health education we can offer most often fails to take into account local perceptions of cleanliness, disease and hygiene (Widstrand 1979). Some such perceptions may be impossible to

change and have to be built into any planning, as constraints. It may be that the constraints are not only to be found in comprehensible local custom, but in the minds and attitudes of health educators and planners (Widstrand 1974, Briscoe *et al.* 1978). Donald Curtis has written a short, but well conceived, article (Curtis 1978) on the difference between what he calls the mundane and exotic factors in sanitation planning.

These are best explained by a reference to his two tables — matrices showing the interaction between administration and users:

TABLE 6:2

EVALUATION OF SOCIAL FACTORS IN SANITATION PROGRAMMES

	Administration values and goals	User values, taboos, and objectives
	inherent values	avoidance of dirt
Exotic factors	assumptions about users	avoidance of people (privacy)
		own interpretations of hygiene and health
	scientific objectives	
Mundane factors	low cost to authority	low cost to household
	administrative convenience	organization (if communal)
	operational and maintenance procedures	convenience of householders

Curtis' checklist of questions on latrine misuse has a much wider relevance. They could be used as a departure for new thinking on the planning and management of public facilities programmes:

TABLE 6:3

EVALUATION OF TOILET MISUSE: A CHECKLIST OF QUESTIONS

	Authorities	Tenants
Exotic factors	Are the authorities or architects predisposed to privacy as a value?	Is it offensive to have defecation activities within the margins of the household?
	What assumption do the authorities make about the sanitary habits of their clients?	What emphasis do households place on privacy in toilet use?
		What are the implications of people or dirt avoidance procedures for indoor toilet use? Or for outdoor public toilet use? Or for outdoor private toilet use?
Mundane factors	How much cheaper would private, outdoor toilets be at ground level?	Is there an opportunity cost involved in the use of interior living space for toilets?
	What servicing arrangements are in force?	Do interior toilets smell?
	Does the current design of toilet have adequate waste disposal capacity?	Would unattended children have better access to toilets, if they were outside?
		How could communal facilities be managed in this setting?

Perceptions of the causes of disease are thus important. The prevention of disease and the containment of illness are part of every medical system. Every society has a kind of medical system, but in the societies we are now dealing with, disease has an intensely social and cultural character. Notions of contagion are bound up with world-view, religion, and with perceptions of the powers and the intentions of one's neighbours, friends and strangers. The medical system, especially with regard to contagion and control, is directly hooked into local systems of social organization and social control (Landy 1977). To be ill is not only a medical condition.

However, there is almost always also a kind of "great-little" tradition dichotomy. Major diseases, like smallpox, measles and psychiatric disorders are usually treated by one type of prestigious healer, with excellent contacts with cosmic and other forces. Sometimes, they even have their own gods. Diarrhoea, boils, burns, the setting of legs etc. usually get treated by another, less prestigious healer or herbalist, with quite a good knowledge of the local pharmacopeia (cf., for example, Paul 1975).

Although the little tradition also works and prescribes according to its own etiological ideas, it would certainly be possible to introduce some new treatment procedures or practices, without demanding adjustment to a germ theory of disease or turning the whole spiritual and cosmological system upside down.

Many practices are not wholly "magical" or wholly "empirical", but a mixture of both orientations (and may quite often simply be habitual) (Hughes 1963). To find out what is habitual is not easy. Culture is site-specific; use of water and sanitation facilities is wrapped up in tradition and culture; and a simple lack of knowledge about consequences determines to a great extent the magnitude of any health-related benefits a population may derive from a given water supply system or sanitation arrangement (Saunders and Warford 1976). It may be appropriate here to point out with Kramer (1947) that the difficulty with which even elementary sanitary measures concerning sewage and water supply were introduced in the late nineteenth century in the U.S.A. was due to the fact that they conflicted with an important feature of American culture — the sacredness of private property.

Ritual purity, an important cultural aspect of Hindu life, may to some extent account for the total omission both in the Fifth Plan and the 1977-1978 Plan of any reference to the problem of sanitation.

Two obvious facts may be mentioned: all individuals, groups, families etc. have some kind of place where they get water and there is ample room in the world for defecation. To this may be added that men always have water at home, as it is the woman's job to fetch water. The implication of this cultural fact is that it may be difficult to interest men in new water supplies.

The important link between health and water hinges, of course, on the fact that a safe supply of water is used all through the year by the whole family. Such water must be easily available, more easily than the other types of water; and a key factor is the ease by which users can obtain safe water. There is also some empirical evidence that the closer a family is to protected water, the lower will be the incidence of diarrhoea, because of less water-borne contagion and because increased use of more water for personal hygiene lowers the rate of diarrhoeal disease agents transmitted via the anal-oral route. The cultural implications of this state of affairs is, however, that we really know little about what "close" means and at what minimum distance increased water consumption starts (Cairncross *et al.* 1979).

Furthermore, new installations must not increase other health problems, such as hookworm in wet soil around dripping taps, typhoid in reticulated water systems without chlorination or disinfection etc. (Amin 1977).

The taste of the water should also be acceptable; it does not take much in the way of cultural constraints to stick to one's muddy, brownish, and more filling water, if the new safe water has a salty or acrid taste.

There is obviously a culturally defined or based difference in acceptability between water installations and sanitation and latrine installations.

- It is much easier to accept to use a new water installation than a latrine, provided there is a minimum of effort to explain the benefits of safe water. (This is most often not done and may to a certain extent explain the high failure rates of such installations.) But we have yet to see an installation which has fallen into disuse because of some real cultural problem. Different castes will hesitate to use the same water supply and strive to get their own, but can (to a certain extent, and if needed) use the same supply.

- Water is also "productive" and water installations give central bureaucrats a sense of development, which supports an interest in the financing of the installations.

When it comes to latrine installations the story looks different. There may, of course, be a community pressure on individual families; and instances have been reported where community values are so important that the price for individual family installations matters less than the social price one has to pay for not installing a toilet. But more often latrine programmes have difficulties.

- They cost money and work, are not "productive", and relate to some very intimate individual behaviour. Defecation is intensely personal; and people may want to squat somewhere in the bush where they can see anyone approaching (Kochar 1978).

- It is shameful to be caught in the act, or be seen on the way to the latrine (Calame-Griaule 1965; Feachem *et al.* 1978). Defecation cannot be done inside the house, but must be more segregated from daily living.

- Ritual purity or ideas of purity in many religions (Hinduism, Islam, etc.) rigorously define the individual's behaviour and feelings towards excreta and their deposition. (Feachem *et al.* 1978 contains a wide variety of incidences of cultural interpretations and behaviour in this respect.)

Other aspects of acceptability concern sitting or squatting positions, methods of anal cleansing, and the accommodation of the technology to such preferences. An important factor is again the combination of latrines with other hygienic installations, such as showers or baths. And finally it does not take much exotic culture to avoid smelly, filthy, fly-ridden, and hot latrines. If you are a little kid, the smelly hole may be totally frightening.

Urban peripheries are different from rural areas, but also from urban centres. City services are lacking; sewers from the old city usually end precisely in these fringe areas; water is either carried from far-away taps or bought from hawkers; and latrines are non-existent. Maybe, you do not build any for fear of eviction. Latrine programmes are not perceived as a need, until the situation gets crowded. The failure rate for such programmes has, however, been immense and this depends to a great extent on another facet of culture — the ability, or rather the non-ability, to organize, maintain and operate such installations. Even to find someone who wants to work as a latrine attendant is in many cultures totally impossible (see, for example, who looks after the public conveniences at Heathrow Airport).

Again, there may be differences here between latrine and water programmes. Purchase or building and use of a latrine is essentially an individual decision, in contrast to the group or total village decision involved in the construction of a well. Thomas Fraser has compared two programmes in the Sambalpur district in Orissa (one well programme and one latrine programme) and he gives this table with factors operating for and against the two programmes (Fraser 1968):

TABLE 6:4

FACTORS OPERATING FOR/AGAINST WELLS AND LATRINES

Wells		*Latrines*	
For	*Against*	*For*	*Against*
SCARCITY OF WATER Subsidy Digging season	Maintenance	Low cost	*Inconvenience* Digging season
Separate caste pump wells	Caste purity Disease theory		CONTACT WITH EXCRETA 1. Near house 2. Near gods Disease theory
	Caste Segregation	Prestige	*Division of labour* Men approached

Note: Factors in capitals are considered DECISIVE; those merely italicized are important; those in plain type are of secondary importance.

COMPONENTS OF AN EDUCATIONAL PROGRAMME IN CONNECTION WITH WATER OR SANITATION INSTALLATIONS

Reduction of disease could follow from the installation of new facilities coordinated with change of behaviour. Some changes will follow directly from the installation, but some kind of introductory programme in collaboration with local leaders at the beginning of the use of the new facility would be necessary. Ideally, there should then be a kind of continuation in the form of a sort of sanitary education team or some such arrangement.

Educational projects should ideally be part of a package: water installations, latrine installations, health care and health education. Recent interest in primary health care (PHC) seems to indicate that water and sanitation aspects would constitute a major part of PHC, together with nutrition and maternal/child care (Alma-Ata 1978).

Cairncross *et al.* (1979) discuss a type of village survey to be undertaken to assess the baseline. Such a community diagnosis could contain the following items (Herlitz 1979):

- demographic parameters, housing, standards;
- perceptions of ill health, of relations between water and ill health, sanitation and ill health, of "good" water (organoleptic factors, absence of quarrels etc.);
- water-collecting habits;
- water-use patterns (different sources, handling of water);
- excreta disposal, habits, and beliefs, waste-water disposal;
- changes in sanitation habits between dry and wet seasons;
- traditional sanitation education (home, school);
- washing and bathing customs (age groups differ);
- children's foraging patterns, defecation habits;
- availability of fire wood;

- whereabouts of domestic animals;
- institutions: power structure, dissemination of information, analysis of "communal feeling";
- women's participation in decision-making;
- school attendance.

(Cf. also Alles and Ratnaike 1976.)

It has been argued that village changes in terms of improvements in water-related health are promoted when progressive adult learning interacts with the technologies of water supply and sanitation (Jackson 1979).

This argument leads to the whole set of problems connected with appropriate technology and transfer of knowledge. The International Drinking Water and Sanitation decade, to be launched in 1980 will devote much time and effort to small-scale, labour-intensive, and resource-conservative technologies, which provide a socially and environmentally acceptable level of service at the least social cost.

Another aspect of the educational effort concerns the use of media for health propaganda. Such efforts, which need a very special kind of skill and knowledge have probably succeeded in Tanzania (Hall and Zikambona 1974).

CHAPTER 7

Gaps in Knowledge and Research Suggestions

SELECTION CRITERIA

In the present chapter, a number of central gaps in our knowledge will be summarized and some research problems presented. Some of the research ideas are developed in more detail; others are presented only as ideas. Evidently, the selection of gaps and proposals has been strongly coloured by the ideas of the authors. To a certain degree, other authors would probably have made a different choice.

Education and creation of knowledge constitutes an extremely important tool in speeding up the development process, according to the general experience of industrialized countries. Research is a critical part of this process. The task taken on by the authors is only to present a number of research ideas. It is their general opinion that the actual research should primarily be carried out in developing countries. The building up of research experience, adapted to the different climatic and national conditions in the tropics, is therefore an essential task, necessary not only in gathering understanding of local hydrology but also as a nucleus for education and training. In consequence, research should be carried out in the industrialized countries only to the extent that it is needed as a basis for fruitful technical assistance, for facilitating the process of transfer of knowledge and experience, or as a general catalyst.

It is considered essential that much of the research be carried out in a problem-oriented manner by interdisciplinary teams. In particular, social scientists should take on a more active role in these teams than in the past. Furthermore, future logical aspects are considered to be extremely important, and research should preferably be directed towards finding realistic situations of "rural futures". It seems particularly important to concentrate efforts on critical environments where there appear to be critical resource constraints. The tendency of aggregating projections for countries as a whole (which is very common) should now be repudiated. Instead, environment specific future-oriented research should be carried out for critical rural environments, e.g. where water causes serious soil erosion, or where a watertable is being overpumped. Interest should be directed at resource projections, the uniting of alternative scenarios for the future (of say 20 years from now), and the specification of technologies needed for those futures. Such efforts seem justified by the wish to (i) draw attention to the implications of long-term trends, (ii) influence R and D to work on needed technologies, (iii) improve current development policy and practice, and (iv) improve the lot of poor rural people in the longer term.

Politicians have short time horizons. Somehow, a longer time horizon must be introduced into the decision-making. This is always liable to be politically unpopular. But it is not a hopeless task. What is needed are a few pilot projects. In each, a small group of social and natural scientists, consulting closely with rural people, should work intensively for 1-2 months initially to develop and test the approach.

WATER AND HEALTH

The relationship between health and water is still not very well understood. Although we have come some way from the simplistic ideas of direct relationships between the provision of water and increased health (ROK Plan 1970-74), there are still quite a few problems which need investigation. Some such problems are discussed in this section, some briefly, some more extensively.

A general area where we still know little is what one might call *water-use parameters*. Some such work has been done in connection with schistosomiasis research by the Tropical Disease and Training Programme of the WHO (Dalton and Pole 1978), but yet we know very little about traditional systems of water use and how people in different cultural settings interact with water, how it is stored, how it is used and how it is contaminated. Research into new types of storage methods is very urgent — interesting results have been forthcoming recently from studies in Tanzania by SIDA/The Ross Institute on three-day, dark, closed storage of water in small tanks and the decrease of bacteria and viable schistosomes.

A quantitative and qualitative analysis of the *flow of use of water* through a small village in different cultural settings may seem like a too simple type of research project. However, such a study would yield many interesting insights into microproblems at the grass-root level, as well as include some measuring aspects which would need some thinking. This type of study does not exist anywhere.

The multiple use of untreated water sources will probably increase as a consequence of the International Water and Sanitation Decade. The *bacteriological surveillance* of such sources has been neglected in the past, but there will probably be a need for such surveillance. We need new knowledge on how to operate and sustain different types of organizations for surveillance at low cost; and we need answers to questions like how frequently samples should be taken, the action levels of bacteria, and to problems of indicators measurement, sampling, and analysis under tropical conditions.

It is quite evident that much contamination of water takes place between the collection and the consumption at home. Much diarrhoeal disease may have its origin in the *unhygienic handling or storage of water*. Our knowledge of the handling of water "from the tap and beyond" is most insufficient; and there is a need for a combined engineering and behavioural study of the peripheral end of the water system. This would include the location of taps, home storage vessels and their microbiology, facilities such as laundry-shower units and their effect upon water use, etc. (WHO-DDC 1979).

The *social and cultural aspects of sanitation* is an area where we know very little. A better choice of disease control measures and sanitation arrangements would be possible, if there was greater familiarity with social and cultural determinants. It is typical that we know so much more about the technical aspect of sanitation than of the social (cf. Wright 1978). The IDRC bibliography (Rybczynski *et al.* 1978) has 532 entries, seven of which deal with "social aspects" and a further seventeen with "public opinion". It is easier to discuss the technicalities of biogas chambers and "appropriate technology" than cultural aspects of anal cleansing, defecation behaviour and habits of human waste disposal. Here is a large area of obvious importance where we know very little.

One aspect of this complex of problems which has largely been neglected by social scientists and anthropologists is the whole area of *cultural definitions and management of health*. This is of importance to any environmental health programme. The epidemiology of health includes research on perceptions and standards of health; and that is not very easy. Health is not what is left over, after one has investigated disease (Wellin 1958).

Another idea is to investigate which *existing cultural and social structures could be used especially in diarrhoeal prevention programmes*. There are occasions when concepts of ritual purity coincide with hygienic measures. Whatever the intended religious or magical purposes, some means of sanitation may in fact function to protect health and ward off disease: left-right hand, ritual cleansing, anal cleansing with water, notions of personal cleanliness, in short what Kochar calls positive elements in folk hygiene. Such elements should be included as parts of a system of public health.

Another area where we have so far had little knowledge is in the *seasonality aspects of diarrhoeal diseases* (Drasar *et al.* 1978). The synergistic effects of diarrhoea and other factors, which peak, for example, at the beginning of the wet season, are not well understood.

Diarrhoea in childhood often has dramatic consequences, yet in most studies we investigate the water use and hygienic habits of adults. It is imperative that the water use and hygienic patterns of children be studied in detail and be given greater emphasis than the behaviour of adults. It may be useful to differentiate between different age-groups among children for the purpose of such a study.

The first group is infants and weanlings — the 6-month- to 2-year-old children. Here the mother and her hygienic habits are important. Is the child washed? Children may be kept dirty for religious reasons. If it is washed, where is this done, when, and how often? What are the water needs? Are there any attempts to train the child at this age? As stools of sick children are often highly contagious, an important aspect is the parents' attitudes towards children's excreta. In many societies, they do not have the same offensive character as the stools of adults. Another aspect is the common practice of giving breast-fed children extra water. As this is an obvious risk, one would like to know whether this is necessary in breast-fed children.

The young pre-school children are a second group. We need to know about their defecation habits and how such habits are transmitted socially and whether there is a tradition of careful and strict defecation practices or if the child is allowed to defecate anywhere. The play areas and their hygienic status are important, as, for example, if they are dry or wet, contaminated or not. If latrines are installed, there are additional questions which need to be answered. Is the child using the latrine? If not, is that because it is afraid of using it — some pit latrines may be very scaring — or is the child discouraged by the parents from using it, because they want to keep the latrine clean? Are special children's latrines built and are they safe?

Schoolchildren are the third group of interest. We need to know much more about the sanitary facilities provided at schools and similar institutions and how they are used. Furthermore we need to know more about the best ways of teaching hygiene — both generally and to prevent diarrhoeal disease. The content of such teaching is interesting in the way it affects the hygienic behaviour of schoolchildren, especially if there are different hygienic practices in the home and in the school.

There are other areas which need looking into, such as *problems of method* and how to identify social-science techniques which can be used to evaluate the community's sanitation perceptions and needs and help to explain or predict acceptance,

indifference, or rejection. Ideas of a *marketing programme for water and hygiene* also need to be examined. Water could probably be marketed as any other produce; and there must be a whole gamut of the techniques that usually are used to make us buy things we do not need which could be used to "market" water and the concept of hygiene, such as consumer behaviour theories, techniques of unconscious persuasion, use of radio and TV as advertising media etc.

SOME BIASES

A necessary condition for increased quality of life in developing countries is that the necessary knowledge be generated in the country itself. The targets set by the different UN Conferences are, however, high and involve immense manpower-needs already during the next decade. At the same time, the process of developing adequate education on the national level, especially for professionals, is slow. Developing countries have, therefore, high expectations of skills and other assistance from industrialized countries. This means that "western experts" will continue to play a crucial role during the decades to come.

In consequence, the process of transferring knowledge has to be looked into with the greatest care, in order to analyse what makes such transfer successful and what creates failures. It is evident that heavy imposing of western technology on developing countries in the past has turned out to be questionable. The chosen solutions have been inappropriate from a number of different aspects: economic, social, environmental, and technical. Instead, an adequate and appropriate technology has to be reliable, affordable, fabricable, mendable, and manageable in the social and physical environment where it is introduced.

There are numerous ideas on international systems of exchange of information, including research catalogues, computerized information retrieval programmes, and scientific information centres. By such systems, information on existing technology could be exchanged, studies completed, research underway (and even unpublished information) on file. It would, however, seem quite important that the information be always labelled with details both on the relevant physical and socio-cultural conditions, and on negative impacts encountered in the practical application of the ideas in question. For instance, water-based sanitation technology was developed under conditions of water surplus and created sizeable negative impacts on water quality, severely complicating the re-use of the receiving waters along the receiving river.

In taking responsibility for the transfer of knowledge, one could in fact ask in what way the developed world can and should really take part in the Third World development. It would probably be fruitful to investigate the effect of dismantling all existing international assistance systems, and find out what biases constitute part of the problem. We have to realize that transfer of knowledge and technical assistance is also a way of creating dependencies between countries.

In particular, three biases might be focused in this chapter:
— climatic bias,
— differences in interpretation of "environmental impact",
— biases in the traditional selection of research priorities.

(1) Climatic Bias

The importance of climatic bias, especially when understood in its broadest sense — i.e. including socio-cultural conditions — probably cannot be overestimated. The missing recognition of water-resources assessment, for instance, as a fundamental

base for all rural water development in water-scarce areas, is probably one effect. An illustration is the simplistic view encompassed by some benevolent charity organizations that the solution to rural poverty and illness is found in the punching of holes in the ground. Evidently, the need for quantitative resource assessment looks quite different under water-surplus conditions when there is enough water anyway, and under water-shortage conditions when the size of the resource base presents a very definite physical constraint to local water development.

Another effect is the slow acceptance of a technology that is adequate from social, operational, and environmental aspects for the intended beneficiaries. If technology that is irrelevant for climatic reasons is imported from temperate parts of the world, it will first have to be found — and even accepted — as inappropriate, before a more adequate technology will be looked for. Interesting matters here include the role played by the local foreign-educated elite in delaying the adoption of such a technology. The general phenomenon of climatic bias is probably worth considerable attention. Studies should be made on different effects of bias also in habits and understanding. For example, the role of aid organizations in the transfer of non-feasible technology and management should be analysed also from the aspect of climatic bias. What is, in fact, the contribution of temperate donors to the increase of the problem of non-functioning rural water-supply schemes? The criteria of failure of such schemes should be looked into and especially the role played by climatic and socio-cultural differences between donors and beneficiaries.

It should be noted that designers from industrialized countries have developed a sense of "feel" for good design, which is based on their own experience and which might not be appropriate in another environment. The inappropriateness of such direct technology transfer leads to the requirement of higher-level skills and creates maintenance problems beyond the capacity of the receiving country. This, in fact, means depriving this country of its best management staff.

Questions worth studying are, therefore, the following. What are the biases in the suggestions from the donors? What are the different filters in the transfer process? And what problems emerge when the proposals are presented to the local receivers? How does the information run in the opposite direction — from the final water-users in the tropics to the project producers in the temperate zone? How much do the officials in the industrialized country understand of the socio-cultural realities to be taken into account in the local choice of project and technology?

In order better to understand the pitfalls of climatic bias, comparisons should be encouraged between different zones. As step number one, main differences as to water-availability conditions should be clarified. This is a matter of hydrology, which should be paid attention to in UNESCO's International Hydrological Programme. As a complement to existing descriptive presentations of zonal hydrology, interzonal comparisons should be carried out, focusing on both hydrological processes and hydrological systems, in order to clarify the similarities and to reveal the essential dissimilarities that have to be taken into account.

An immense amount of research on irrigation has been carried out in the U.S.A. during the last century. Transfer of knowledge would seem possible — but what are the factual constraints? Both hardware and software have to be taken into account, i.e. also services, institutional patterns, attitudes.

In this connection, a focus on the behaviour of agricultural scientists would be interesting. In agricultural research in the temperate zone, water is not treated as a scarce resource. If it were known how widespread scarcity conditions are, how much scarcity matters, and why scarcity develops, agricultural education,

training, and research might be made much more relevant and useful. Donors could support sabbaticals for Third World academics to enable them to write textbooks that are appropriate for their own conditions of water availability.

The project should be a study of the education, training, beliefs, values, and research behaviour of agricultural scientists in areas where water is generally scarcer than land. The project should be performed by transdisciplinary researchers working along different approaches: by reading, as a participant-observer on research stations, interviewing agricultural scientists, and surveying agricultural research designs and findings. It could be worth studying not only developing countries, but also former colonial powers (for example Britain), going back some 40 years, where some important bases for attitudes towards the problems might be found.

The project might also be extended to study engineers in a similar manner.

(2) Differences in Interpretation of "Environmental Impact"

Environmental concern has developed strongly during the last few decades, both in developed and in developing countries. The UN Water Conference explicitly recommended countries to see the avoiding of negative effects on both environment and human health as one of the main objectives of every water-related project. In fact, developing countries have an inherent advantage in introducing environmental quality in the multi-objective planning process, as they are generally committed to planning already, and therefore could easily provide for anticipated environmental effects as an additional step in their current planning efforts.

To the extent that negative environmental impacts should be kept low, they act as constraints on development. A conflict thus develops between short-term benefits and long-term environmental deterioration. The questions then arise: Benefit for whom? Deterioration from whose point of view? There is also the conflict between benefit for the individual or benefit for the society as a whole. In selecting strategies to solve such conflicts, the time perspective of different groups in society enters the stage: for the starving rural population the primary problem may well be to survive irrespective of a possible reduction of the resource base for future generations. It may be that the local elite embraces the same views, although for other reasons.

Some cultural aspects of differences in time perspective might contribute to our understanding of the impression of lack of interest exhibited by local decision-makers with regard to the risk of serious environmental deterioration in the future. Such conceptual matters seem worth closer study. For instance, in international contexts, there is sometimes a tendency by participants from developing countries to neglect environmental impact, claiming it to be a matter of luxury to be approached later when a larger degree of economic freedom has been created.

There is no doubt that the process of transfer of experience between regions is made more difficult by the broadness of the concept of "environment" which evidently creates a risk of misunderstanding. It is, therefore, important to start analysing and structuring the general concept along the lines suggested in Chapter 2, in order to create a better base for discussions between developing and industrialized countries. Evidently, different aspects of environmental quality have to be discussed separately, in order to reach conclusions on how medium-term impacts should be handled in different environments.

Primarily, a strategy for avoiding unnecessary future deterioration by water-related projects decided on today, is a question of awareness, i.e. understanding what the deterioration would mean to the local man, and how it will develop as years pass by. The tool for such understanding is education on all levels, including professionals, technicians, skilled labour, extension workers and the general public. Secondarily, it is a question of creating both interest and will in developing adequate countermeasures. Relevant questions in this phase include the following: What reduced benefits might be acceptable to avoid soil deterioration that would create starvation conditions in the next decade or two? How much would the present generation of farmers be willing to give up to secure the resource base also for the next generation?

The many different aspects of environmental quality make it necessary to consider some priorities. Evidently, irreversibility seems to be an aspect that should qualify for highest priority, especially when the resource base would be affected irreversibly. In conclusion, great attention should be paid to soil conservation measures, including risks for both soil erosion, and salinization and waterlogging, two areas that today are responsible for massive soil deterioration in the tropical zones.

POLICY AND PLANNING

There are several reasons for our *imperfect understanding of the planning* process in society. One fundamental reason is to be found in the task itself, namely to transform goals and objectives, often very imprecisely and vaguely formulated, into rational expressions for an action programme applicable to specific sectors of the society. These sectors do not behave rationally in the true meaning of the word, but they present dynamic features that to some extent are the result of an inner societal development affected by outer influences, such as policies, planning directions, etc.

In this complicated situation, models and systems borrowed from the natural sciences are applied to the human societal system. The success of this approach has generally failed to materialize (Biswas, 1979). These methods are based on the rational use of mathematical expressions based on relations between clearly definable quantities. Since characteristic quantities in human adaptive systems are not well defined and are, moreover, of an intangible character, application of such models and systems may give reliable results only in very restricted cases.

Whatever the success of models and systems may be, decision makers need to make conclusions from analyses that as far as possible reflect the complexity of the problems stated. A fundamental gap in our knowledge thus immediately presents itself: we need a better communication and *understanding between modellers and decision makers*. It is of great importance that the problems which engage the decision makers are adequately presented to the modellers. On the other hand, the way in which a problem has been analysed mathematically by the modellers must be intelligibly submitted to the decision makers. "There has been a proliferation of unvalidated, untested, and useless models, many of which can be classified somewhere between dilettantism and academic exercises" (Biswas 1979).

One of the most fundamental gaps in knowledge of policy and planning is the lack of correspondence between ideal and real planning. To some extent, the gaps in our knowledge already mentioned may be included in this concept. The notion of ideal planning assumes that all kinds of information needed for a reliable planning outcome are at hand or attainable. As we know, sufficient data are seldom accessible, but, nevertheless, the planning procedure is carried out. Lack of data may mean such diverse things as lack of fundamental hydrological and demographic data, or incomplete information of the society in general. We may, thus, lack

awareness of the public's reaction to, and perception of, the proposed actions. To be more precise, there certainly exists some relation between inaccuracy of data and deviation from a desired outfall of goals. This may justify detailed studies of the extent to which goals and objectives may be attained when given various degrees of incomplete data.

The problem of *discrepancy between plan and reality*, of course, must be discussed in the context of the role of plans. A substantial literature exists on the ideal role of the plan or of a plan, much less on the outcome of plans. The preparation of the planning document often takes an inordinately long time and involves much expense and labour. Often, much less expense and labour seem to be devoted to the practical carrying out of the suggestions of the plan, if they are carried out at all. A study of non-planning planning in the water field might yield some interesting insights, for example of the role of the quality of the planning document in generating aid flows compared to the role for such aid flows of results and achievements in the field. This leads to another area of concern, namely *evaluation* and the feedback from implementation experience to the planning process.

The inertia in this feedback leads to difficulties in finding adequate solutions. In our opinion, this is one of the most important problem areas in the field of water-resources planning, as planning presumes an evaluation by means of checking characteristic, pre-selected quantities or indicators. Without this type of checking we cannot be sure of having put an adequate plan on paper or into practice.

One aspect of this problem is that evaluation has often been carried out as a finger-pointing exercise and allocating blame for non-fulfilment of plans left and right. Or, evaluation is looked upon as some kind of simple audit exercise to look after the donor country tax-payers' money and protect it from graft or corruption. Both of these approaches are, of course, not correct; and they are based on a misconception of the content of evaluation procedures and, indeed, of the philosophy of evaluation, if any. One has to recognize the right to be wrong. Decisions are taken on the basis of the knowledge available at one point in time. However, knowledge and experience develop and change. Society changes and reality changes, and rather quickly at that. Evaluation thus becomes a means of adapting to new conditions, as well as producing an input in the ongoing planning process of experience during the running of a project.

For some ten years, we have talked about evaluation as a necessary planning ingredient, but still very little is done about it, mainly because of a combination of lack of interest among donors and producers and because of lack of research to produce manuals or evaluation procedures.

MANAGEMENT PROBLEMS

(1) Management of Irrigation Systems

The potential for increased agricultural production and more equitable distribution of water to farmers on existing medium and large irrigation systems is probably enormous, not least because production potential has been greatly enhanced by the new agricultural technologies developed in the past ten years. But performance on most irrigation systems is very inefficient and falls far below expectations. It is rare to find economists' cost-benefit calculations justified, planners' expectations fulfilled, or governments' targets achieved. Most projects bring under effective command much less land than was planned. Cropping intensities usually fall far short of projections. Water deliveries to farmers are often unreliable. The supply of water is frequently very inequitable, with those at the head receiving more than their fair share, and those at the tail receiving supplies which are small, uncertain, and untimely, if indeed they receive any water at all.

Diagnosis tends to be inadequate because of disciplinary blinkers. Engineers are concerned with physical works and water flows, agronomists with crop water requirements, sociologists with organization and access within communities, and economists with these narrow views — bigger and better works and maintenance for the engineers, more predictable and appropriate water deliveries for the agronomists, methods of conflict resolution for the sociologists, and water pricing for the economists — tackle the central questions of how, in practice, water is, and should be, controlled and allocated by bureaucratic irrigation organizations. This is a gap in knowledge. Again and again, studies suggest that the decisions and actions of engineers, water supervisors, water guards, and the like are critical for more productive and more equitable distribution of water; yet almost nothing is known about them.

The reasons are not only narrow disciplinary specializations. Irrigation staff are also probably more difficult to study than, say, an engineering system, the water requirements of a crop, a village community, or the cost of water. Often, they are, it seems, subject to strong political pressures, to threats and to inducements. Their roles are intensely political, in that (except where water is very abundant) they are involved in allocating scarce economic goods to farmers. If irrigation management is to be improved, it has to be made rational for them to behave in ways which will be very unpopular with some people — especially the often more influential top-enders who tend to get water at the cost of tail-enders. To see how to make such behaviour rational, the work, lives, problems, and relationships of irrigation staff have to be understood.

This requires research which may be as difficult as it is important. It requires something of the approach of social anthropology applied to a dispersed, probably defensive, and often corrupt, bureaucracy. It requires a sympathetic understanding from the inside of what happens at present, which can lead to sound prescriptions for improvement.

Since this is a new focus, research methods may have to be innovative. Many questions pose challenges to judgement and ingenuity: Where to start (in a village? at the top of the organisation? in the middle?)? How to explain the purpose of the research? How to protect, and to be trusted to protect, informants? How to avoid unduly altering actors' behaviour by the observers' presence? How to find out what really, normally, happens? And, above all, how to make the leaps from understanding to prescription and from prescription to change? If those challenges can be tackled and overcome, the effects on production and on rural equity should be dramatic.

Administration of Water-use Systems

Far reaching and overwhelming targets have been set up for the extension of water supply, sanitation, and irrigation for the following two decades. The development so far does not, however, promote a positiveness corresponding to the targets. There are too many examples of project failures, many of which may be attributed to administrative failures. In most instances, the organizations are hierarchical but with inadequate liaison between levels and within levels, i.e. the necessary feedback loops are missing. Therefore each part works more or less in isolation, which badly influences the final results of the projects.

Many of the institutional difficulties are said to emerge from the wrong attitudes and low capabilities of the personnel involved. It is more and more advocated that local people should be involved, not only in the planning stage, but (what is even more important) in the operation and maintenance of water-use systems. But there are many questions to answer before this can be put into full practice: What administrative organizations are suitable? Why is there a lack of feedback in the hierarchical systems? How does one get local people involved?

If planning should be done, not only for the people, but also with the people, it seems to be a fruitful way to develop systems which involve choices by the local users themselves and the corresponding responsibilities. However, it is highly questionable whether outsiders can impose consumer participation which extends beyond the mere provision of manual labour. Each cultural environment and each state of development have their own attitudes towards organization and administrative behaviour. This means that the research should not centre on a specific administrative system, but rather involve studies of the local organizations already developed in different cultures.

This research falls mainly within the field of the social sciences. It requires a careful approach as it deals with the attitudes of people; and as a collorary to the view that specific systems cannot be transferred to, or imposed on, societies, the research is probably best performed by interdisciplinary teams basically recruited from their own cultural environments.

An understanding of the behaviour of local organizations, such as farmers' associations, would certainly improve the basis for sound water administration. If the social constraints of such organizations could be systematized, the potential for well performing water-use systems would most probably greatly increase.

The management of large-scale systems has been discussed earlier in this section. It is important to mention that we have very little knowledge of the management of *small-scale systems*, of small-scale agriculture, of the decisions and decision procedures or decision ambitions of the small group or even the single farmer. The use of excess household or irrigation water for small-scale vegetable growing, the use of waste water from the household for useful purposes are areas which need research as well as the performance of small-scale irrigation programmes. There is an increasing volume of literature on small-scale irrigation from South East Asia, but precious little about the performance of small-scale rural water and sanitation programmes.

(3) Water Pricing

Water pricing is a policy question. Whatever policy is chosen mismanagement often occurs. If water is not charged, funds for the operation of water schemes have to be budgeted and raised from somewhere else. If there is a charge for water, it is necessary to provide possibilities for revenue collection. To take a decision on water pricing requires strong political commitment for success. Therefore, it is often devastating, if donor agencies impose their own attitudes as a condition for transfer of project funds.

There is a very high rate of failure of water-supply projects existing without revenue collection. This may call for the introduction of collection systems in as many projects as possible -- one reason being that pricing would give incentives for water savings, another that paying for water would give users a sense of ownership. On the other hand, there are examples showing that these hypotheses do not hold and that revenue collection is very difficult to manage.

It seems to be apparent that pricing policy and the revenue collection system can not be generalized. Systems can not be transferred from one location to another, without knowing the conditions behind each system. A systematic analysis of the factors determining success or failure of different systems seems to be fruitful for the implementation of pricing policies. It should, however, not be necessary to limit the studies to water-supply projects. Other sectors, involving distribution of goods or infrastructure, may provide good examples.

Research into pricing systems seems to fall mainly within the fields of economic and social sciences. What is the real value of water to the consumer? What is the cost of metering and revenue collection? How to get the user to understand the value of the product? Why do some systems function in some localities and not in others? Answers to these and other related questions are likely to promote sound pricing policies as well as revenue collection systems which could help to finance the water-supply development.

COMMUNITY PARTICIPATION

One area of concern in water and sanitation programmes is the whole concept of *community involvement and public participation.* Usually, the involvement consists of the provision of manual labour in water and sanitation programmes. It is, however, obvious that communal participation means something else, namely participation in decisions about the planning and implementation and the sharing of the benefits of installations. There have been many different mixes of community participation and national programmes. Thus, in some places, construction has been left to self-help programmes, whereas the operation and maintenance has been done by the government. In other places, the government has done the constructions, whereas the local community have been responsible for the operation and maintenance. The long-term costs of alternative strategies, as well as the financial impacts of participatory programmes, such as effects on fee collection and savings to public funds, are questions about which we still know little.

This area is obviously an area of research which goes far outside the more precise research objectives of a water research programme, but it is important to note that in most successful sanitation and water programmes that have been studied, community participation *sensu lato* has been an important ingredient, and thus, must be greatly increased in further programmes.

(1) User Attitudes to Water

In most developing countries where design criteria exist, these are primarily adopted from European and American practice. This has led to a number of disadvantages, for example, less appropriate design and evaluation criteria, as well as less appropriate technology for the water-use systems. Along with this, goes the lack of defined goals for water development and difficulties in breaking down the goals into subgcals. These missing links often mean that projects are planned and constructed on the basis of wrong premises, eventually leading to complete failures.

Today's design criteria usually neglect a site's specific natural, as well as social and cultural, aspects. There are many results of this neglect to be seen, for example continuously used pumps designed for intermittent use, taps used by women but designed on the basis of criteria drawn from men, toilets which are not used because they do not face the appropriate direction, total lack of spare parts because local blacksmiths and manufacturers are not acquainted with the material. The social and cultural background thus seems to be important, as this forms the origin of development goals and thus also of manageable criteria.

Research should, therefore, be carried out on users' attitudes to different water-use systems. In design and location of water sources, the knowledge and ideas of local people should be used, as they are more adapted to local natural conditions than most visiting specialists. After all, water has been used since the beginning of mankind and today there is a wide spectrum of development stages to see and to learn from.

Analysis of people's interaction with water in traditional systems in different cultures and stages of water-use development is a difficult task, again mainly in the field of social science; but efforts in this field could promote a firm basis for design and evaluation criteria. With such criteria it is likely that water systems would be much more appreciated by the end users than is the case today.

CONFLICT MANAGEMENT

In any conflict, whether over scarce resources or visions of the future, there is always a trend to find a solution. Such resolution mechanisms may, of course, differ in appearance, from conflict resolution through violence to less intense mechanisms for accommodating demands.

Conflicts over water tend to mobilize a very high degree of energy and to be very intense in character, probably because actors and group members are deeply involved with one another and highly dependent on the water supply (Coser 1956, 1967). We know, however, very little about such conflicts; and the suggestions referred to below must be regarded as temporary.

It is of course impossible to avoid conflict, and it may be asked whether one should in fact try to. Some tension is certainly productive and generates new and better solutions. An interesting question is the acceptable level of conflict in a society and in a social field. There are compromises, and workable compromises too — especially in the constant conflicts over finance between ministries. Such compromises lead to less conflict, but at times also to non-optimal solutions.

In irrigation, we know very little about precisely such problems. Conflict-resolution mechanisms may be suggested at different levels. At one end of the spectrum is the necessity of land and water reform, which really would touch the heart of the matter. Short of suggesting land reform, there are a variety of smaller, and maybe easier, suggestions to put forward. One concerns the role of administration in conflict. Many conflicts are obviously caused by vacillation, indecisiveness, and fuzzy guidelines from politicians and policy makers. In many cases, this unclearness is further complicated by an inability of the administration to analyse political decisions, to make policy decisions and translate the political message into operative policy, spelled out in detail in guidelines, manuals, and clearly defined chains of command and responsibilities. Much inequity in water systems may be alleviated by clear decisions about who is responsible for what in the water allocation process. Government priorities translated and condensed into useful, workable manuals are lacking almost everywhere.

It is also important for the administration to be quite clear about the *sequelae* of decisions and where conflict can be prevented by administrative changes. This needs a type of bureaucrat who is very scarce, at every level in the hierarchy anywhere. The opportunities to prevent conflict in the administrative arena are something about which very little is known. Opportunities must be found in both communication and control and in the capacity to mediate between groups and between objectives (Harriss 1976). One must ensure that the views of disadvantaged irrigators are heard. Government must also pursue consistency in similar schemes — as the Sudan has found, farmers are quick to seek redress against discrimination (Thornton 1975).

The administration must also understand local forms of collective behaviour, and understand how to use it for the benefit of all. The creation by government of cooperatives or local associations for water control are doomed to fail unless there is a thorough understanding of the mechanisms of such institutions and how they fit into the rest of the society they are supposed to help. The organization of local decision-making structures is also important, as there must be more

to communal participation than the mere provision of manual labour. On the other hand, it is not absolutely certain that more discipline comes automatically with more democratic ways of decision-making (Thornton 1975). The combination of stricter discipline, reliable water supply, and conflict is poorly understood, as are indeed the ways of making a water-allocation system (in the words of Robert Chambers) "burglar-proof".

It is probably true — as has been shown by Pasternak from Taiwan — that if access to irrigation water is equalized in terms of time and quantity, there will be fewer water conflicts (Pasternak 1968).

A necessary background for the management of water is, of course, a functioning legal system and legal provisions for the handling of water problems. Water laws require time consuming and intricate research to be adapted to the prevalent legal system and the cultural and political climate of the country. Such research is at present not very well developed and there are few results forthcoming, except for questions of the use of international rivers.

The opposite to conflict is cooperation. In the flora of UN reports over recent years, cooperation and concerted action between men, between administrative units and ministries are called for in one way or the other. It is often not realised that it is not enough to call for cooperation — the way such cooperation is to be brought about must be spelled out in detail. We do not know how, but we do know that, there is an area about which we know very little, except the fact that it is not possible only to call for cooperation without realizing very clearly that there are real problems of conflict within administrations and that some arise out of the nature of the relationship between local and supra-local institutions (Harriss 1976).

(1) International Rivers

Planning of shared water resources is a major area of concern, not only in Africa where most of the countries are dependent on transnational rivers, but also in Asia, South America and the Middle East. It is a fact that cooperation on transnational rivers has not worked very well, although this is not always clear from reports of international river commissions. It constitutes an extremely complicated area where the time perspective continuously changes, as new sectors of society develop, modifying the pattern of water use as the years go by. Existing guidelines (Helsinki rules) are based on European and American legal practice and are possibly subject also to "climatic bias".

Research is badly needed in the field of shared water resources. Here we have to approach two main issues. Firstly, there is need for the development, by a suitable international body, of a *code of conduct*, giving adequate rules to follow in line with the equitable-share principle. A matter of some importance is to find principles adapted to the fact that river-basin development is a dynamic process, where the pattern of costs and benefits continuously changes with time. Thus, the code has to be so clear that it is possible to apply it to a certain case without negotiations over decades.

The second main issue is the *persuasion process*, where new ways have to be found to overcome the primitive views of sovereignty expressed today. A close analysis should be made of the possible positions of governments, trying to find constructive ways of developing more open-minded approaches. The crucial point is probably the creation of new forms of incentives and disincentives. Each country along a transnational river needs to understand more fully the implications of schemes under discussion. For example, the implications for the flow of the Nile from Khartoum downstream will depend on the decisions of the Ethiopian government

to remove substantial amounts of water from the Blue Nile, the Sudanese project of selling Blue Nile water to Saudi Arabia, and of planned extraction for irrigation purposes in Kenya from the rivers that flow into Lake Nyanza and in northern Tanzania from the lake itself.

One approach to this very important and truly interdisciplinary research area might be to do some case studies on the resolution of past conflicts, for example on the Indus or the Nile. Very little is available in developing countries on how such conflicts are solved. It should be added that extreme caution must be exercised when transferring experience from, for instance, the U.S.-Canadian or from Middle-European contexts to international river basins in the tropics, as the actual pattern of incentives and disincentives is probably crucial and quite dependent on both climatic and socio-cultural conditions. A truly interdisciplinary group should be created to analyse the area and see what could be developed.

WATER AND LAND

Past experience has demonstrated the need for a better understanding of the dualistic interaction between water and land, highlighted both by the importance of exogenous rivers for the development of ancient irrigation societies in dry climates, and by the hazards of soil mismanagement for soil moisture conditions, and water quality. Flood management and drought management constitute two sectors, where an understanding of this interplay might find immediate applications. It would also become possible to avoid some of the most serious environmental impacts of water projects, and to develop adequate and coherent measures for land and water conservation.

A crucial element needed for a watershed management that will be successful also in a long-term perspective, is improved knowledge on water pathways and processes involved in infiltration and runoff formation, in the development of environmental impact from human interference with the natural water circulation system, and in the dispersion of pollutants.

Another element of special relevance to water management under arid and semi-arid conditions is a better acceptance of large-scale fluctuations as part of climatic reality, especially in monsoon-dependent regions. This involves a close understanding of the atmospheric processes involved.

The authors wish to highlight three areas with relevant gaps in knowledge and large research needs:

- improved methods of assessment of the existing water resource base,
- essential couplings between atmosphere and hydrosphere,
- plant-land-water interactions.

(1) Water Assessment

In spite of the millennia-long general understanding in Europe and Asia of water as a dynamic resource, assessment of local water resources has not been considered fully necessary as a basis for rural water development. It is not very long ago that such assessment was in fact considered a research task, rather than a necessary prerequisite for water development to be undertaken as a routine activity. In effect, as late as 1977, the UN Water Conference had to draw particular attention to the importance of this seemingly self-evident activity.

Here, we are concerned with the determination of how much water is available from hydrological aspects, i.e. the general conditions, regional and temporal patterns of infiltration, groundwater formation and flow, and river runoff. But at the same time there is also the problem of how much and in what way this hydrologically available water could be made accessible in the fields, villages, towns and industries.

During the last century, much experience and hydrological know-how has been developed, especially in the temperate zone, and numerous textbooks present graphs and equations describing interdependencies between meteorological, hydrological, and landscape factors. However, due to large hydrological dissimilarities between different climatic zones, this know-how cannot be automatically transferred to and applied in other regions. It is, therefore, a matter of importance that local hydrology be studied on a regular and institutionalized basis in all countries, in order that rules of thumb, graphs, and interdependencies are checked and models developed on the operation of local hydrological systems.

The basis for this checking, testing and modelling is data collection in networks of hydrological observation stations, hydrogeological mapping, etc. Data have to be synthesized and models developed in order to find methods to predict availability in areas and localities without observations. Hydrological institutes constitute a crucial part of the infrastructure of a country already at an early stage of development. Research areas of importance include the development of methodology applicable in remote areas and under harsh climatic conditions, capable of catching also extreme events such as sudden flash floods, local showers, etc. Better methods should be developed for groundwater assessment, especially groundwater formation, aquifer patterns and characteristics.

Water-accessibility problems are of a general character, but are also regionally quite different. In some areas, the most interesting part of the available water is shallow and readily accessible groundwater; in other areas, there is only deep groundwater. In some areas, most of the groundwater is artesian, or even fossil. In other areas, it may be foreseen that the problems of increasing shadow populations of future generations will make water imports a very realistic activity, for which adequate technology, legislation, and administration has to be developed, be it interregional water transfers, iceberg towing or rainmaking operations.

(2) Atmospheric Links

Numerous developing countries are situated in the monsoon-dependent zones where intermittent periods of drought constitute a typical climatic characteristic. A delayed acceptance of droughts as an inevitable reality would result in further food catastrophes.

Different activities are called for. Good rainfall stations have to be developed and used as a base for choice of crops and agricultural methods of soil-moisture management. As an important step in the right direction the efforts of ICRISAT deserve strong support. Continued and expanded atmospheric research is needed to clarify the links between the different atmospheric systems involved in the configuration of the intertropical discontinuity and the generation of monsoon systems.

Taking into account that the energy inputs and losses involved in ground-based human activities now start to approach the order of magnitude of natural phenomena causing climatic fluctuations, it is evident that the mutual interactions of atmospheric and hydrological processes constitute a research area of primary importance. It has to be clarified to what degree and by what processes the atmospheric water-circulation system will be affected. Global mathematical

modelling of the water cycle might contribute to a better understanding of the expanded role to be played by water resources in moderating effects of anthropogenic energy inputs. Geographical areas of crucial interest, when it comes to long-term effects on agricultural production and human life, are areas on the margins of the monsoon systems, especially densely populated areas like the Ganges valley.

(3) Plant-Land-Water Interactions

The link between vegetation and water operates in both directions: plant production is dependent on water — with a certain content of dissolved nutrients — being available to the roots; but, at the same time, the existence of a plant cover is crucial in directing water between different parts of the runoff production processes.

This area is truly interdisciplinary and approached on different areal scales by different disciplines. Whereas agricultural research is often preoccupied with small-scale phenomena, clarifying interactions between subparts of the plants and surrounding media of air, soil, and water, hydrological research favours an order of magnitude corresponding to the catchment area. As a matter of urgency, scientists from the different groups should intensify their cooperation. In order to reduce the human obstacles to apply the knowledge, social scientists are invited to enter the teams, especially as it is in the interactions between plant, land, and water that we find processes and phenomena crucial for the development of irreversible environmental impact, that threatens future food production in large parts of the tropics.

Even if we have been fully aware for several millennia of the importance of water for plant production, there are a number of research problems that deserve attention. The water processes in the unsaturated zone and the interplay with root systems and groundwater should be studied in tropical surroundings, especially under arid and semi-arid conditions. Water economy of different plant species, the possibilities of controlling and improving it and the manageability of water use by different crops, constitutes one important research area, which should be expanded to include the development of new species and types with better water economy. The introduction of water availability as one of the criteria applied in the selecting of crops for an area, and the socio-cultural obstacles for its application present themselves as very interesting research problems. It might be interesting to study some real cases of adaptation to increasing conditions of water deficit: the decreasing groundwater resources in the Coimbatore region in India might be interesting also from this aspect. What are the crucial cultural processes behind the choice of rice as a crop also in areas of water scarcity and how could they be controlled?

One important role in the interaction between water and plant is played by the salts dissolved in the soil water. Here, we approach the problem of soil productivity and man as a soil-maker rather than a parasite on soil or, even worse, as a soil disease. Three research problems might be especially focused. Innovations in the field of chemical fertilizers should be supported, to find substances that get into solution in a rhythm adapted to the actual needs of the plants. The second concerns the whole and widespread complex of salinization-waterlogging, where the problem in general seems to be more of human obstacles to applying already existing knowledge on the necessity of attaining a salt-water balance in the soil, than missing knowledge as such. Thus, the problem here seems to be more of a massive failure to transfer knowledge to the peoples most concerned, rather than in the understanding of the basic phenomena. This problem deserves high priority, due to the large impact on future food production in vast areas in arid and semi-arid countries. The third problem is related to the transport of nutrients, emanating from organic products and human life, to the groundwater. If

the vegetation is poor, a large proportion of the nutrients may find its way down to the groundwater and, if the infiltration is rare, appear as quite high nitrate concentrations, the health hazard of which presents an interesting problem.

As stated earlier, the existence and character of the plant cover plays a crucial role in exposure to erosion and the processes of formation of groundwater and river runoff, and should be studied from hydrological aspects. The application of this understanding is important, as it refers to combined soil and water conservation, i.e. what is sometimes referred to as watershed management. Some problems to be approached here are — besides the purely hydrological ones — the socio-cultural obstacles to a more widespread application in sensitive tropical areas of terracing and reforestation, measures that have been known for thousands of years. Studies should be made to show the importance of a link between land-use planning and planning of water projects. Here again, we are concerned with problems of environmental impact of an irreversible character, that has to be impeded by advance planning, because it is practically impossible to rectify it retrospectively. We are speaking of using soil conservation as a measure of water conservation, in fact, conservation of both water quantity and quality. Environmental degradation of watershed areas should be studied in different regions. One should try to identify measures to reduce degradation and develop an administrative and legal framework within which the technical measures can be effectively implemented. The last of these is particularly difficult (watershed management usually falls between the responsibilities of many agencies — forestry, agriculture, soil conservation, irrigation, animal husbandry) and the conservation-oriented agencies (forestry, soil conservation) usually have much less political backing than the production-oriented ones. Again, a programme of action research, in collaboration with governments, seems essential.

The experience in the U.S.A. is that it is easy to have soil conservation included, because the farmers see the benefits immediately. The returns are very quick. The African experience is exactly the opposite — only hard work with no visible returns. Lesotho has long passed the point of no return. Soil conservation is the number one national problem, and yet one sees very little being done effectively. The problem is primarily a question of land-use policy, which is practically non-existent today.

Another essential research area is the development of the environmental-impact assessment methods needed in water-project planning, in order to find in advance measures against environmental hazards from planned projects of water and land development. Such methods have to be based on a profound understanding of the processes involved. Experience developed in industrialized countries should be systematized from the point of view of possible applicability in tropical environments and soils. Local research has to be developed in different type environments characteristic of the different kinds of tropics.

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